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THE METABOLISM OF ALCOHOL IN THE ANIMAL BODY

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In 1913 the Nutrition Laboratory of the Carnegie Institution of Washington proposed a tentative plan for the study of the psychological and neuromuscular effects of alcohol on the one hand and on the other hand for the study of the physiological and the chemical processes occurring in man after the ingestion of alcohol. The part of the program dealing with the effects of alcohol on the psychological and neuromuscular processes has had important contributions made to it by Dodge and Benedict and subsequently by Miles.

From time to time studies have also been made upon the chemical side with respect to the changes in chemical processes when alcohol was ingested. These studies have been continued without regard to the changes in the legal status of the consumption of alcoholic beverages. The use of alcohol in beverages has been world-wide for centuries. Consequently the problem of the chemical transformation of alcohol in the human body is not one solely of national concern. At least one nation, the French, obtains as many calories from alcohol as from protein.

Absorption and Recovery

Another reason for continuing these studies is that alcohol has a number of unique characteristics as a material that can be introduced and transformed in the body in quantities comparable with those of the nutrients generally used, protein, fat and carbohydrates. Alcohol is very rapidly absorbed in the body. The direct determination of the rapidity of its absorption in the human body is extraordinarily difficult because of the problem of recovering the unabsorbed portion, but the rate of absorption of alcohol can readily be determined with animals that can be sacrificed at the end of the period in which the absorption is studied. Although alcoholic beverages are usually taken by mouth, the use of alcohol in enemata has been carried on for many years in medical practice. This method of introduction makes it possible to study the rapidity of absorption because the unabsorbed portion can be recovered by

TABLE 1

Absorption of 7.5 Per Cent. Alcohol Solutions when Introduced into the Rectum of Human Subjects

Subje	Date	Alcohol solution Volume	Alcohol solution Weight of alcohol	Perio injec retai		Appa absor of alc
		cc	gm	hrs	mins.	per cent.
C	Mar. 1..	265	19.9	3	10	99.9
D	Mar. 3..	265	19.9	4	4	100.0
A	Apr 10.	350	26.3	1	0	98.0
C	Mar. 22..	415	31.1	3	15	99.9
A	Apr. 15.	500	37.5	1	4	87.4
C	Apr. 18..	810	60.8	5	43	99.4

cleansing enemata. In a series of studies conducted at the Nutrition Laboratory, the absorption of alcohol from enemata was found to be extraordinarily rapid. Table 1 shows the results of one series of experiments on the rate of absorption of 7.5 per cent. alcohol solutions when given as enemata to human subjects.

This property of rapidity of absorption brings about a quick distribution of alcohol through the whole body because it is readily diffusible in body tissues and fluids. Alcohol has another unique property in that as long as it is still present in the body it can be identified and recovered and in animals, when the animal is sacrificed, the total amount of alcohol remaining in the whole body can readily be determined. In this respect alcohol is unlike other materials that are commonly consumed because it is not possible, for the most part, to follow the course of the usual three nutrients very readily after they are eaten.

Protein, for example, is almost immediately altered in character so that the original material can not be identified again. Certain types of fats may be identified by their peculiar chemical characteristics. Only one of the sugars, dex-

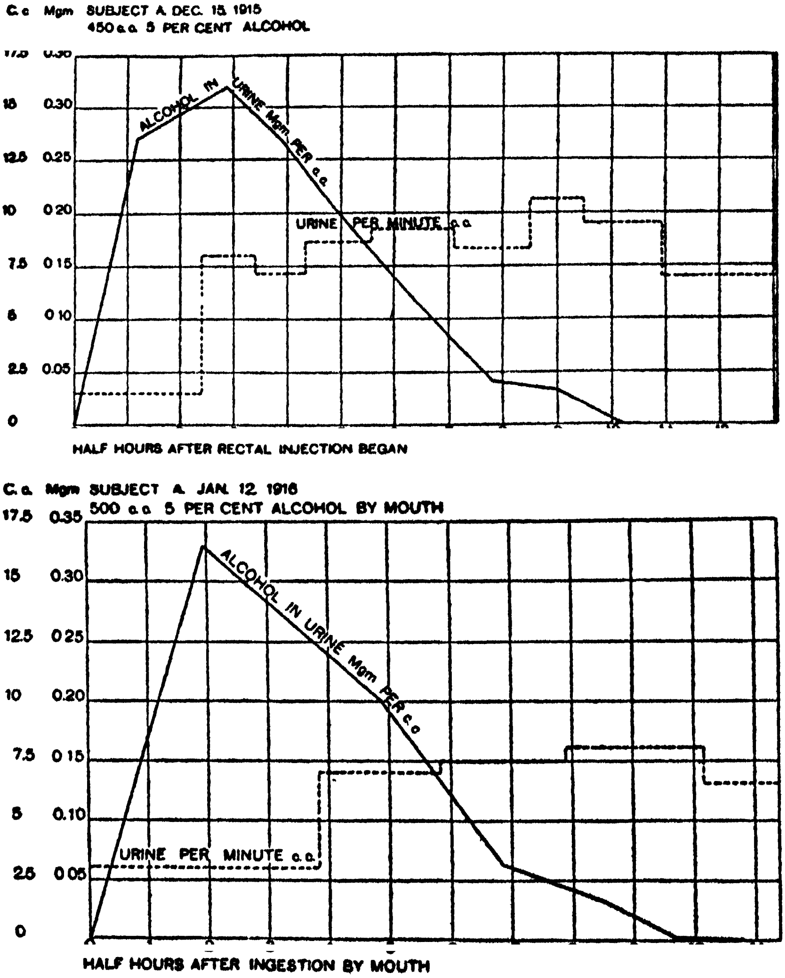

FIG. 1. CURVES SHOWING THE ALCOHOL PER CC OF URINE AT DIFFERENT INTERVALS AFTER THE INTRODUCTION OF 450 CC OF 5 PER CENT. ALCOHOL RECTALLY AND 500 CC BY MOUTH.

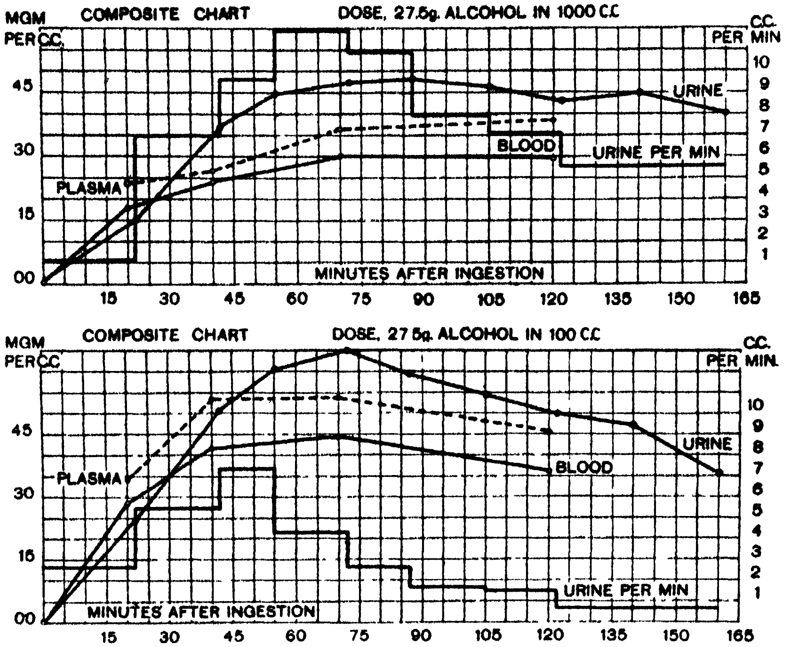

FIG. 2. CHARTS SHOWING THE AMOUNTS OF ALCOHOL IN THE WHOLE BLOOD, PLASMA AND URINE AFTER THE INGESTION OF 27 5 GRAMS OF ALCOHOL IN 1,000 CC AND IN 100 CC OF WATER (AFTER MILES).

trose, can be followed with any degree of certainty, but even in this case it is not known whether the dextrose determined is that actually given, or whether it may not have come from some other source in the body itself so that it is practically a replacement material.

Because of the chemical property of the recoverability of alcohol it is possible to follow the rapidity with which alcohol disappears from the tissues and fluids and thus have an idea of the rate of its transformation. For example, alcohol very quickly appears in the urine after it is once introduced by mouth or rectally. If the urine is collected periodically the alcohol may be determined quantitatively, and the concentration followed from time to time. In Fig. 1 are shown the curves of the concentration of alcohol in the urine after the rectal injection of 470 cc of 5 per cent. alcohol and after the taking of 500 cc of 5 per cent. alcohol by mouth. The maximum concentration was attained in one to one and one-half hours and at the end of five hours there was no longer any alcohol in the urine.

In a similar manner we may follow the alcohol in the blood by withdrawing samples of blood periodically and determining its amount. The alcohol in the blood is parallel to the alcohol in the urine, so that if one has either the urine or the blood the rapidity with which the alcohol is transformed in the body can be followed.

Fig. 2 shows some results obtained by Miles at the Nutrition Laboratory on the comparison between the alcohol in the blood and that in the urine when 27.5 grams of alcohol were given in a dilution of 2.75 per cent. or as 27.5 per cent. alcohol. The dilute alcohol was used because these observations were made at the time that there was an intense interest as to whether this concentration of alcohol was intoxicating. The figure shows definitely the marked parallelism between the alcohol in the blood and urine and that the alcohol in the urine is always slightly higher than that in the blood, regardless of dilution.

After the ingestion of alcohol it may also be detected in the breath, as is evident to bystanders in the vicinity of any one who has taken a noticeable quantity of alcohol. It should be noted that not only alcohol may give an odor but also other volatile compounds which are present in the liquid in which the alcohol has been taken. It is because of the constant association of these odors with alcohol that we assume that an individual has taken alcohol. Alcohol may, therefore, be determined in a definite volume of the breath and from this, again, is gained a knowledge of the rapidity with which alcohol disappears from the body. Table 2 shows some results obtained by Liljestrand and Linde on a comparison of the alcohol in the expired air with that in the alveolar air, that is, the air in the deepest part of the lungs, and that in the blood. There is a marked parallelism between the alcohol in the blood and that in the expired or alveolar air. In about 2 liters of air, there is the same amount of alcohol as would be found in 1 cc of blood.

TABLE 2

ALCOHOL IN THE EXPIRED AIR, ALVEOLAR AIR AND BLOOD AFTER THE INGESTION OF 45 GRAMS OF ALCOHOL DILUTED TO 150 CC (AFTER LILJESTRAND AND LINDE)

After ingestion of alcohol	Alcohol in 2 liters of expired air (31°)	Alcohol in 2 liters of alveolar air (31°)	Alcohol per cc of blood
mins	mgm	mgm	mgm
10	0 42	..	..
13	...	0 43	..
24		.	0 49
27	0 60		.
28	..	0 64	...
53		...	0 65
56	0 65		...
57	...	0 78	...
78	0 65	...	...
79	..	0 73	..
100	.	..	0 67
114	0 53	..	..
116	.	0 53	.
142	0 41		.
144		0 43	.
153	..	..	0 54
164	0 40	...	...
166	.	0 41	...
185	...	...	0 43
190	0 36	...	...
191	...	0 32	...

These three methods of determining the amount of alcohol present in the body at various intervals after its introduction are of extreme value in determining the rapidity with which alcohol is transformed in the body and how long it still is present.

RESPIRATORY QUOTIENT

Alcohol has another unique property chemically because of the mathematical value of its respiratory quotient when it is completely oxidized in the body. When materials are burned in the body, there is a production of carbon dioxide that is eliminated mostly in the breath and an absorption of oxygen from the air that takes place in the lungs. The volume of carbon dioxide divided by the volume of oxygen in this process is called the *respiratory quotient*. Table 3 shows the respiratory quotients for alcohol and for the three substances which are ordinarily introduced into the body in our food; protein, corresponding to meat, fat of various kinds, and carbohydrates, such as sugars and starch, which are finally transformed into glycogen and stored, when the supply is low or burned. The highest respiratory quotient is obtained with such materials as sugars and starches, and the lowest respiratory quotient under ordinary conditions would be obtained if nothing but fat were burned.

TABLE 3

RESPIRATORY QUOTIENTS (R Q.) AND HEAT PER GRAM OF NUTRIENTS AND ALCOHOL

	R Q.	Calories
Protein	0 81	4.40*
Glycogen	1 00	4 20
Fat	0 71	9.50
Alcohol	0 67	7 08

* Heat value when burned in the body

Ordinarily a mixture of these three substances is burned. The level of the respiratory quotient will be determined primarily by the proportions of carbohydrate and fat that are burned. In the combustion of alcohol, there are two volumes of carbon dioxide given off for three volumes of oxygen used and the respiratory quotient is 0.67, which is outside the range of the respiratory quotients usually obtained in the burning and transformation of the ordinary foodstuffs used. Also alcohol furnishes energy. The amount per unit of weight is between the amount furnished by fat, the highest, and the amount furnished by starches and sugars, the lowest

A consideration of these different respiratory quotients shows that if alcohol is burned in large quantities in the body, the respiratory quotient should be lower than when no alcohol is burned. In the study made on alcohol in the urine when alcohol was introduced in two different ways, determinations of the respiratory exchange were also made in order to ascertain whether there was an effect on the respiratory quotient and for the purpose of calculating the amount of alcohol that was burned.

When, however, these results were assembled it was found that although there was a depression in the respiratory quotient, as would be expected, it was not large. The amounts given were such that alcohol disappeared from the urine in about five hours. When calculations were made of the amount of alcohol that was burned, based on the amount of oxygen used and the respiratory quotient on the one hand and on the disappearance of alcohol in the urine on the other hand, there was a discrepancy between the two results. The amount obtained from the respiratory exchange was lower than the amount obtained from a measurement of the alcohol in the urine. Part of the difficulty was the uncertainty as to what kind of materials alcohol replaced when it was burned. The question then arose as to whether there is any particular tissue in the body in which alcohol could be stored and retained.

Distribution in the Body

Therefore a study was made of the distribution of alcohol in the various tissues and organs of the animal body. For this purpose domestic fowls were used, and as alcohol is very readily absorbed from the air in breathing, a system was used in which the animal was placed in a chamber with an atmosphere saturated with alcohol vapor. The animal then inhaled alcohol with each breath, and there was an accumulation of it in the body. The animals were allowed to remain in the chamber for 2 to 29 hours. They were then killed and the various tissues dissected and the amount of alcohol present in each tissue was determined.

It was soon found that these animals absorbed considerable amounts of alcohol in this manner. The amounts remaining in the body at the end of the exposure varied widely, and in general the quantities were proportional to the duration of the exposure, although this was not always strictly true. As a rule the blood had the highest amount of alcohol per unit of weight and those organs that had a large supply of blood, brain, kidneys, spleen, heart, lungs and liver, had alcohol per unit of weight that nearly approached the amount per unit of weight of blood.

Fig. 3 shows the relationship between the amount in the blood and the amount in the liver and that of the whole body and that of the portion called the remainder, namely, that left after the various tissues and organs had been dissected. The two intersecting straight lines within the figure, or the two axes, represent the concentrations. Where these lines cross, the concentration is at zero and extending along the lines in each direction horizontally or vertically the concentration increases according to the scales shown at the bottom and at the left-hand side of the figure. If the amounts of alcohol per unit of weight were the same in all four portions, then the figures would be perfect squares. If on the contrary one tissue had no alcohol in it, the figures would be triangles. In the central portion of this figure for the most part, three concentrations tend to form two sides of a square, namely, the whole body, the blood and the remainder. On the contrary, that of the liver shows very low alcohol when the rest of the body has also not much alcohol in it, but much lower than the other portions. If, however, the concentration in the blood increases with the different animals, the concentration in the liver tends to approach that of the blood. It is interesting to note that those animals in which the amount of alcohol per unit of weight of the liver was low in relation to the other parts showed no effects of alcohol, thus no signs of intoxication. However, when the liver came to have a concentration somewhat more nearly like that of the blood, then the animals began to show signs of intoxication.

Other relationships of the blood to the other portions of the body are shown in Fig. 4, in which there are included for purposes of comparison the whole body, the skin and the fatty tissues. The fat had extremely small amounts of alcohol per unit of weight in comparison with any other tissue and thus could not serve as a place of storage for alcohol. In fact, from a general survey of the results obtained in this study there is no organ that can store alcohol. The amount present is primarily dependent upon the amount of blood circulating through the particular tissue, although the capacity of the individual tissues to metabolize alcohol undoubtedly also plays a rôle.

It is interesting to note that in some cases the brain had concentrations of alcohol approaching and sometimes even exceeding those of the blood. Also, as these fowls were mature, occasionally

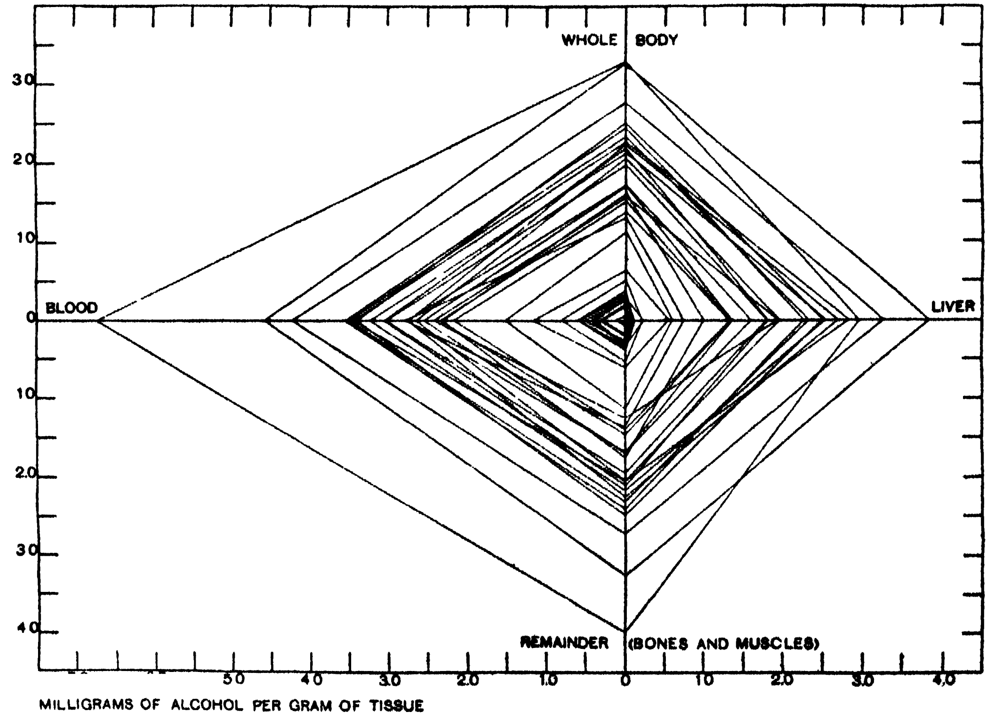

Fig. 3. Equilibrium polygons formed from the plotted concentrations of alcohol (milligrams of alcohol per gram of tissue) in the blood, whole body, liver and remainder (bones and muscles). Zero concentration is at the intersection of the axes of the figure, and the concentrations are plotted along the horizontal and vertical axes. The points for each hen are connected to form a polygon.

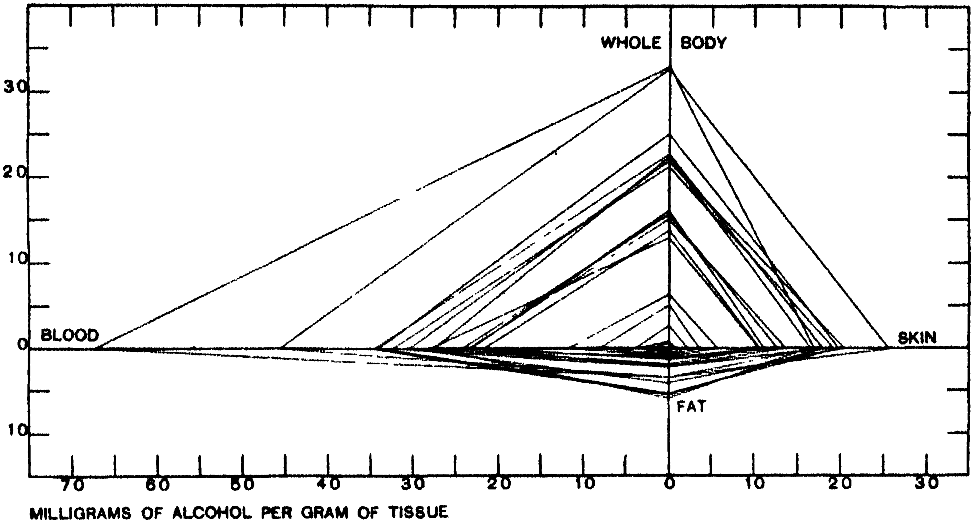

FIG. 4. EQUILIBRIUM POLYGONS FORMED FROM THE PLOTTED CONCENTRATIONS OF ALCOHOL (MILLIGRAMS OF ALCOHOL PER GRAM OF TISSUE) IN THE BLOOD, WHOLE BODY, SKIN AND FAT.

there were present either masses of incompletely formed eggs or even whole eggs with shell on them at the time of killing. Invariably the eggs, even those with shell, showed noticeable amounts of alcohol, even though the time of exposure was short. The nervous system and the reproductive system are two tissues of vast importance for the proper functioning of the body and for the continuation of the race.

Table 4 gives the relation between the concentrations of alcohol in the various tissues and that of the blood. In general the relation is constant, regardless of whether the concentration of the alcohol in the blood is low or high, with the exception of the liver. When the amount of alcohol per unit of blood is below 2.5 mgm the ratio of the alcohol in the liver to that in the blood is much lower than when the amount of alcohol in the blood is above 2.5 mgm. In general this is the dividing line between those animals which showed no intoxication and those that did.

One very important ratio is derivable from this series, namely, the ratio between the concentration of alcohol in the whole body and that of alcohol in the blood, which is about two thirds. If the alcohol in the blood is known, the total amount of alcohol in the whole body can be estimated by multiplying the body weight by two thirds of the concentration of alcohol in the blood. This is of importance for estimating the amount of alcohol not only in animals but also in human beings, as these ratios have been confirmed by several investigators, more particularly by Widmark for humans, so that it is now possible from the analysis of blood to calculate the actual amount of alcohol present through the whole body.

In the study of the distribution of alcohol with fowls a record was kept of the activity during the time of exposure. When these animals were arranged in order of activity it was found that those in which practically no activity was visible showed high concentrations of alcohol, whereas those that had almost continuous activity showed low concentrations of alcohol. It was not known whether these differences between quiet and active animals were due to a possibility that the animals that were quiet had a low capac-

TABLE 4

RATIOS OF CONCENTRATION OF ALCOHOL IN THE VARIOUS TISSUES IN HENS EXPOSED TO ALCOHOL VAPOR

Number of hens	Hours exposed	Concentratio in blood	Average ratio of concentration in tissue to concentration in blood											
			Brain	Heart and lungs	Liver	Kidneys	Spleen	Alimentary tract	Skin	Fat	Muscle	Remainder	Eggs (immature)	Whole body*
		mgm												
3	2	0.24	0.8		0.2							0.6†	0.7	0.6
1	3	0.52	0.7		0.2							0.5†	0.3	0.5
4	4	1.76	0.8		0.3							0.7†	0.6	0.7
3	8	2.57	0.8	0.7	0.7	0.7	0.8	0.7	0.6	0.1	0.8	0.6		0.7
6	16	2.17	0.7	0.8	0.7	0.8	0.8	0.8	0.5	0.1	0.8	0.7		0.7
4	29	5.01	0.9	0.8	0.7	0.8	0.7	0.7	0.5	0.1	0.7	0.6		0.6

* Does not include alcohol in feathers

† Remainder includes the organs not analyzed in addition to the portion usually remaining after dissection.

ity for utilization of alcohol and therefore soon became intoxicated, which naturally would bring about quietness, or whether they were due on the other hand to an actual increased combustion of alcohol as the result of activity. The importance of determining whether alcohol is burned during activity is twofold. In the first place, it would be a contribution to the problem as to the source of energy for muscular work. This problem has engaged the activities of physiologists for many years. Also it would be of practical value in cases where the individual has taken so much alcohol that he has become intoxicated and some means are necessary for restoring him to sobriety. If muscular work increases the combustion of alcohol, the individual ought to exercise.

EFFECT OF MUSCULAR WORK

A systematic study of the effect of muscular work on the rapidity of alcohol utilization in the body was made with a human subject. The respiratory exchange was first measured to ascertain whether during muscular work the respiratory quotient would be lower with alcohol than without alcohol. The general procedure was to have the subject rest for one hour during which the base line for the day was measured. Then the solution for the day, either a control or one containing 30 or 50 cc of alcohol, was given him and the measurements were resumed and continued for three hours. On some days these three hours consisted entirely of rest. On other days the subject worked either one-half hour, one hour or two hours and the balance of the three hours was used for a recovery period.

Table 5 gives the excess respiratory quotient during work and recovery on the alcohol and non-alcohol days. By excess is meant the extra amount of carbon dioxide eliminated and extra amount of oxygen used above those that would have been found for the subject had he been at rest the entire time. This gives an indication of the character of the extra material used during muscular work. If, for example, all the work performed had been done with carbohydrate as a source of energy, then the excess respiratory quotient would be 1.00. On the contrary, if the material used on the days on which alcohol was given consisted largely of alcohol then the respiratory quotient would be lower than on the days without alcohol.

In the first group, in which the subject worked for one hour, the excess respiratory quotients on the control days and on the alcohol days were practically the same. In the next group there is only a difference of 0.03 between the control

TABLE 5

RESPIRATORY QUOTIENT OF EXCESS GASEOUS EXCHANGE OF WORK AND RECOVERY WITH AND WITHOUT ALCOHOL (TOTAL PERIOD OF WORK AND RECOVERY, 3 HOURS)

1 hr. 275 kgm p m 2 hrs recovery		½ hr 550 kgm p m 2½ hrs recovery		2 hrs. 275 kgm p m 1 hr recovery		
Control	50 cc alcohol	Control	50 cc alcohol	Control	30 cc alcohol	50 cc alcohol
0 85	0 85	0 90	0 87	0 84	0 87	0 85
0 86	0 84	0 90	0 87		0 88	
0 85	0 85					

days and the alcohol days. This difference can hardly be considered significant In the third group, not only is the respiratory quotient on the alcohol days not lower than on the control day but is even higher on the days on which 30 cc of alcohol were given at the beginning of work This absence of any definite finding of the effect of muscular work and alcohol on the respiratory quotient led to further studies as to the effect of muscular work on the disappearance of alcohol.

The metabolism of alcohol can be studied by determining from time to time the alcohol in the tissues and fluids of the body. In the study on muscular work the urine was collected for the entire period of time of work and of rest following work to ascertain whether, in spite of the absence of any definite result with the respiratory quotient, there would be any evidence that actually there was less alcohol present in the body when muscular work was performed than during rest.

The results are shown in Table 6. With 30 cc of alcohol there was but a slight difference. This difference is within the range of differences that might be found, provided a larger number of experiments were run. In the group with 50 cc of alcohol there are two groups in which the amounts are identical. It is true that the other three columns show slightly lower figures than the rest experiments. However, the general lack of uniformity and definiteness in these results implies that the muscular work has not reduced significantly the amount of alcohol.

TABLE 6

CONCENTRATION OF ALCOHOL IN URINES FOR REST EXPERIMENTS AND EXPERIMENTS DURING MUSCULAR WORK AND RECOVERY (5 TO 6 HOURS) (MILLIGRAMS OF ALCOHOL PER CUBIC CENTIMETER)

30 cc alcohol		50 cc alcohol				
Rest	2 hrs 275 kgm p m 1 hr recovery	Rest	1 hr 275 kgm p m 2 hrs recovery	½ hr. 550 kgm p m 2½ hrs recovery	1 hr rest ½ hr 550 kgm p m 1½ hrs recovery	2 hrs. 415 kgm p m 1 hr recovery
0 34	0 29	0 75	0 63	0 53	0 75	0 61
0 33	0 30	0 79	0 66	0.59	0 76	0 69

Frequent measurements of the alcohol were then made by determining the alcohol in the ventilating air current of the respiration apparatus. This alcohol must have come from the expired air of the subject. The results with 30 cc of alcohol are given in Table 7. In one group of experiments the subject rested the entire three hours and in the other he worked at the rate of 275 kgm per minute for two hours (equal to level walking about 3 miles per hour) and then rested for one hour. After the third 15-minute period after the ingestion of alcohol there is no significant difference between the amounts of alcohol in the expired air in the two types of experiments. The table shows that in three hours the alcohol has nearly disappeared from the expired air. This would indicate a complete utilization or disappearance either by metabolism or by elimination of this amount of alcohol in that period of time. The utilization of 30 cc in three hours is a rapid rate and is equivalent to 174 calories, nearly 1 calorie per minute. This would nearly equal the energy output of an average man sitting quietly. Because the measurements were not continued until it was absolutely certain that all the alcohol had been utilized, it is diffi-

TABLE 7

CONCENTRATION OF ALCOHOL (MGMS PER LITER) IN EXPIRED AIR IN EXPERIMENTS AFTER THE INGESTION OF 30 CC OF ALCOHOL IN REST EXPERIMENTS AND EXPERIMENTS WITH MUSCULAR WORK (2 HOURS AT 275 KGM PER MINUTE) (15-MINUTE PERIODS)

Kind of experiment	Periods after ingestion											
	1							8		10	11	12
Resting experiments	0.32	0.20	0.17	0.10	0.10	0.07	0.08	0.05	0.05	0.05	0.03	0.03
	Work periods								Rest periods			
Work experiments ..	0.17	0.12	0.12	0.10	0.09	0.07	0.06	0.06	0.04	0.02	0.02	0.02

cult to estimate the exact time of the disappearance of this amount of alcohol. In the values recorded in the literature there is rarely, if ever, a value as high as this for the metabolism of alcohol with man.

There were, finally, experiments in which was determined the alcohol in the urine, in the blood and in the expired air. The subject in this case rode an ergometer for one hour after receiving the alcohol. Samples of urine and blood were taken. He then again rode for an hour and the sampling was repeated, and then he rested for two hours. On the rest day the same routine was followed, with the exception that the subject rested the entire time instead of working. In Table 8 are given the results for the blood and urine. The findings on the alcohol in the expired air were essentially the same as in the preceding experiments. There were no significant differences in either blood or urine between the values on the rest day and those on the work day.

TABLE 8

ALCOHOL IN BLOOD AND IN URINE AFTER THE INGESTION OF 50 CC OF ALCOHOL IN RESPIRATION EXPERIMENTS WITH A HUMAN SUBJECT (MILLIGRAMS PER CC)

Kind of experiment	Blood	Urine	Kind of experiment	Blood	Urine
Work at 415 kgm per min			Rest throughout		
1 hour's work	0.77	0.91	1 hour .	0.67	0.80
1 hour's work	0.48	0.63	1 hour .	0.46	0.60
1¼ hours' rest	0.19	0.24	1¼ hours	0.26	0.30

The conclusion was drawn that the performance of muscular work after the ingestion of alcohol did not affect the rapidity with which the alcohol disappeared in the body. The only effect muscular work can have on the amount of alcohol in the body is to remove some of it by simple vaporization through the breath. But in these experiments it was found that the actual amount of alcohol removed by the breath during muscular work was only twice as much as that during rest and the maximum percentage of the total alcohol ingested that was removed in any case by the breath was 1.6 per cent. Any attempt to remove alcohol through increased ventilation would require a perfect whirlwind through the lungs in order to be really effective in diminishing the amount of alcohol in the body.

Similarly, the amount removed in the urine was not over 1 per cent. Although it is true that by drinking more water or fluids more alcohol would be eliminated in this manner, the amount that could be removed through flushing would require gallons of water in order to be effective and these large quantities should be taken immediately after taking alcohol, because the amount of alcohol gradually diminishes of itself and there would be no point in taking large quantities of fluids when the alcohol in the body had reached a low point.

It has been found that there is a diminution in the alcohol in the expired air, in the urine and in the blood after its ingestion, but on the other hand we have not been able to ascertain by means of the respiratory exchange or by a study of distribution what has become of the alcohol. The difficulty is in the calculation of the kind of material that alcohol would replace. For this purpose are used the nitrogen in the urine, which represents

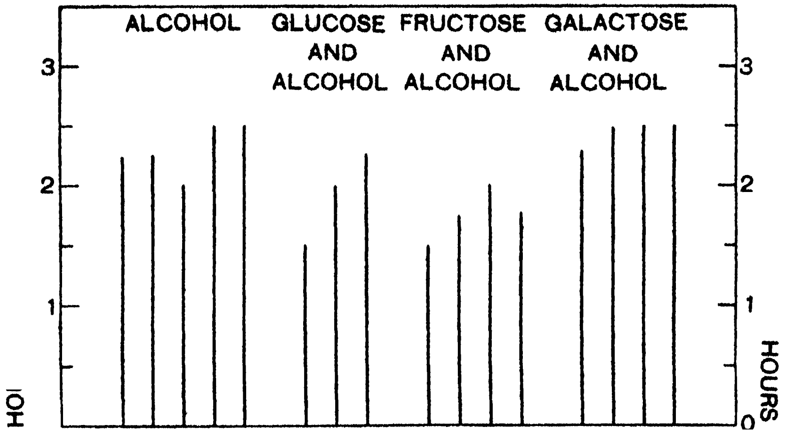

Fig. 5. Duration of alcohol in the human expired air after the ingestion of 15 cc of alcohol alone, and after the same amount of alcohol with 46.5 grams of glucose, fructose or galactose.

the protein burned, and the respiratory exchange, which represents the sum of the combustion of protein, fat and carbohydrates. When alcohol is also introduced into the body and its effects are added to the respiratory quotient, a situation is produced in which four substances are dealt with and it is not known which of the usual three substances, namely, protein, fat and carbohydrates, alcohol replaces or whether it replaces all three according to their proportions of the amount that is burned at the time of ingestion of alcohol. In all previous work the latter has been assumed. The two materials that have the greatest effect on the respiratory quotient theoretically are the carbohydrates at one end and fat at the other, and in the absence of a marked lowering of the respiratory quotient after the ingestion of alcohol it is conceivable that it is not carbohydrate that is replaced but rather some other substance.

The Effect of Sugars

Mellanby found in his first investigation on the metabolism of alcohol that, when food was ingested along with the alcohol or shortly before the taking of alcohol, there was not so great a rise in the alcohol in the blood as when no food was ingested. At first the effect of food was ascribed to the slowing of the absorption of alcohol. If the effect of food was to slow the absorption of alcohol, we would expect to find that alcohol remained in the body a longer period of time when food was taken than when no food was taken. This, however, is not the case. Some foods actually increase the rapidity with which alcohol disappears.

On the hypothesis that it was not carbohydrate that was being replaced by alcohol but something else, a group of experiments were made in which alcohol was given with and without the addition of sugars. For this purpose there were used the three sugars that occur either naturally or as the result of breaking down of food, namely, glucose, the sugar which occurs in blood, fructose, which occurs in sweet fruits and as a result of the hydrolysis of cane sugar during digestion, and finally galactose, which comes from the splitting of milk sugar during digestion. As pointed out before sugars will raise the respiratory quotient and alcohol should depress it. The problem was whether the sugars would be burned as rapidly when taken with alcohol as without alcohol and what the effect of the sugars was on the disappearance of alcohol in the body.

In Fig. 5 is shown graphically the time during which alcohol was found in the expired air when alcohol alone was given and when alcohol was combined with the three sugars. At the left, the group with alcohol alone shows a longer appearance of alcohol in the expired air than when alcohol was taken with either glucose or fructose. Fructose very definitely hastened the disappearance of alcohol. On the contrary, galactose did not accelerate the disappearance of alcohol.

Fig. 6 shows the comparison between the respiratory quotients obtained when glucose was given alone and those when glucose was given with alcohol. Here there is a very marked contrast between the respiratory quotient after sugar alone and that after alcohol and sugar.

The plan of these experiments was based on the idea that the respiratory exchange should be measured and the alcohol in the expired air determined until the alcohol had disappeared. Corrections could then be made for the alcohol eliminated by way of the expired air and the urine and it could be assumed the remainder of the alcohol had been metabolized in the body, and by metabolized is meant presumably burned. After the respiratory exchange had been corrected for the carbon dioxide and oxygen due to alcohol, the amounts of other materials burned were calculated and a comparison was made of the results obtained on alcohol days with those obtained on the days when no alcohol was given.

When this was done with the experiments with glucose, it was found that we were justified in the hypothesis we started with, namely, that alcohol replaced something else other than carbohydrate. Table 9 shows the changes in the metabolism of carbohydrates and fat after the ingestion of 46.5 grams of glucose and of 15 cc of alcohol, given separately or given together. In the two groups in which alcohol was given there was a marked lowering of the fat metabolism, but there was an increase in carbohydrate combustion whether the glucose was given alone or with alcohol. Alcohol definitely replaced fat in the metabolism.

Referring to the respiratory quotients again and comparing the respiratory quotient of fat (0.71) with that of alco-

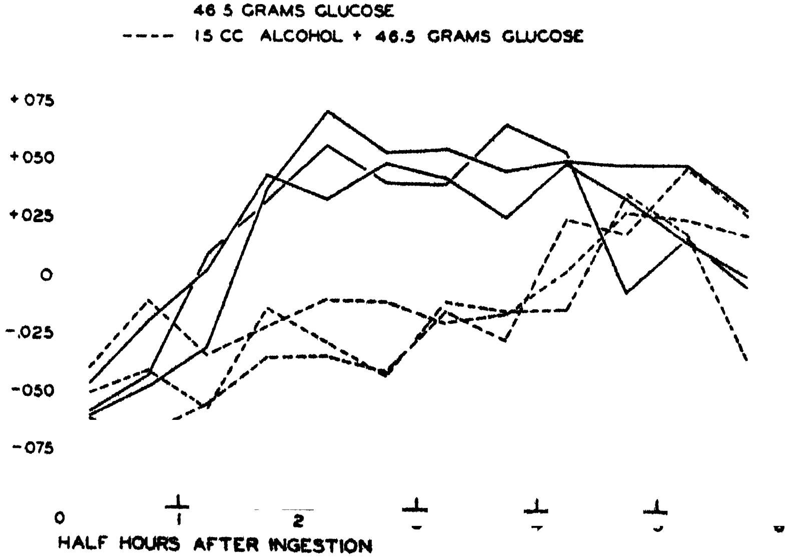

FIG. 6. THE CHANGE IN THE RESPIRATORY QUOTIENT FROM THE PRE-INGESTION LEVEL AFTER THE INGESTION OF 46.5 GRAMS OF GLUCOSE AND AFTER THE INGESTION OF THE SAME AMOUNT OF SUGAR WITH 15 CC OF ALCOHOL.

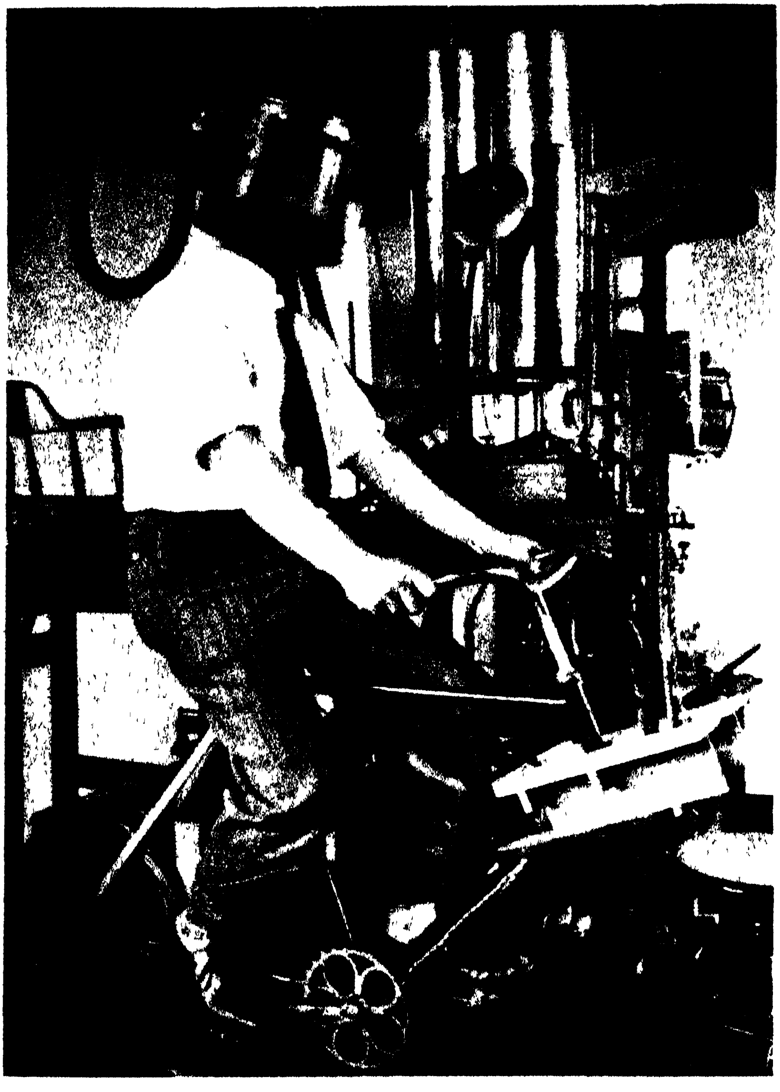

FIG. 7 PHOTOGRAPH OF BENEDICT HELMET RESPIRATION APPARATUS AS USED FOR THE STUDY OF THE RESPIRATORY EXCHANGE DURING MUSCULAR WORK WITH AND WITHOUT THE INGESTION OF ALCOHOL.

hol (0 67), a marked difference is not observable Therefore, if alcohol replaced fat in the metabolism, the respiratory quotient would not be markedly affected. This seems very definite evidence that alcohol when ingested by man either replaces fat in its combustion or else is converted into some kind of material with a respiratory quotient resembling that of fat.

H. H. Mitchell has recently found that if alcohol is added to a complete diet for rats, there is in the tissue gained by the animals traceable to alcohol a greater amount of fat than is produced from the basic diet alone Now if alcohol is burned in the body, it furnishes energy, and from the amount ingested a calculation can be made of the proportion of the total energy expended in a given period

TABLE 9

EFFECT OF WATER (CONTROL), ALCOHOL, GLUCOSE, AND GLUCOSE AND ALCOHOL ON THE METABOLISM OF CARBOHYDRATE AND FAT (GRAMS INCREASE (+) OR DECREASE (–) IN THREE HOURS)

	Carbohydrate	Fat
300 cc water	– 1.4	+ 2.2
15 cc alcohol	– 2.8	– 6.1
46.5 grams glucose	+ 1.3	– 0.7
15 cc alcohol 46.5 grams glucose		

of time that is supplied by alcohol alone, provided that all the alcohol is metabolized In the experiments with fructose and glucose the alcohol disappeared from the expired air in most cases at least by the end of the experiment. It therefore seemed justifiable to assume that the alcohol had been burned or metabolized

When a calculation is made as to what proportion of the energy under these conditions can come from alcohol, we find it relatively high, namely, at least 40 per cent In a few experiments higher concentrations of alcohol were given along with dry sugar. In these experiments the alcohol disappeared much more rapidly than in the experiments with more dilute solution In fact, if a calculation is made on the supposition that the duration of alcohol in the expired air represents only the period of time in which alcohol is present in the body, the absurd result is found that over 100 per cent. of the energy can come from alcohol This points to one conclusion, namely, that instead of the alcohol being burned, the disappearance of alcohol is due to its conversion into some other substance which may either be stored or utilized in the body.

A number of other investigators have been working on the effect of hormones on the rapidity with which alcohol disappears in the body The most effective one is insulin, a substance that is used in the treatment of diabetes. Very marked increases in the disappearance of alcohol have been found with animals after the injection of insulin Here again the amounts of alcohol estimated as utilized in the body are so large that it is not reasonable to suppose that they represent actual combustion

It would seem as though this is one of the lines for future investigation, that is, whether there are any conditions under which the disappearance of alcohol is so rapid that it can not be accounted for solely by combustion These studies can best be carried on by a combination of methods, namely, measurement in some way of the actual presence of alcohol in the body fluids or expired air and at the same time a measurement of the total respiratory exchange in order to estimate the total energy expended during the entire period of time. The theoretical value of such experiments is great from the standpoint of pure physiology and biochemistry alone, and the practical value of any knowledge of the way in which the disposal of alcohol is brought about in the human body needs no elaboration

SUMMARY

Alcohol is readily absorbed by the animal body and its presence after absorption can be detected in the blood, urine, and expired air until it has disappeared either by elimination or through metabolic processes. Alcohol is distributed throughout the body mainly according to the blood supply of the various tissues and organs The disappearance and metabolism of alcohol are not accelerated during increased muscular activity. This conclusion is based on the determinations of respiratory quotients and on the determination of alcohol in blood, urine, and expired air. Studies with sugars and alcohol, in which the respiratory exchange and the alcohol in the expired air were continued until the alcohol had disappeared, showed that alcohol replaced mainly fat in the metabolic processes.

THE STORY OF WHALING

A PARABLE OF SOCIOLOGY[1]

By Dr. JOHAN HJORT

PROFESSOR OF MARINE BIOLOGY, UNIVERSITY OF OSLO, NORWAY

IN "Moby Dick" you'll find this charming sentence "I stuffed a shirt or two into my old carpet-bag, tucked it under my arm, and started for Cape Horn and the Pacific Quitting the good city of old Manhatto, I duly arrived in New Bedford "

As the intellectual center of the New England coast, where whaling has been an important factor during the three centuries which we are now celebrating, Harvard itself is intimately associated with the history of whaling In times of expansion, success and prosperity as well as in periods of decline, failure and poverty, whaling was the very first industry on the high seas

I was very pleasantly surprised to receive the invitation to deliver a lecture on the story of whaling in this center of tradition and at this historical meeting. I beg to accept the invitation as a representative of the Norwegian whalers It may truly be said of these countrymen of mine, what Herman Melville writes on your own whalers of former days "Often, adventures which Vancouver dedicates three chapters to, these men accounted unworthy of being set down in the ships common log "

Some years ago a Norwegian captain, somewhere in the Ross Sea, took his floating factory in between two rapidly approaching icebergs to liberate his catchers which had stuck in the ice. "It is nothing to speak of," he said to me. "I saw that my men were in danger and took them out." I was glad at that moment that no personal adventures ever figured in the reports from my own expeditions and believe that I agree with all whalers if I by this occasion confine myself to scientific problems and facts only But, to quote Herman Melville once more "If you declare, that whaling has no aesthetically noble associations connected with it, then I am ready to shiver fifty lances with you there, and unhorse you with a split helmet every time "

I was no less pleased to accept this invitation as a biologist. It encouraged me to hope that this great meeting will mark a change in the valuation of scientific ideals—a sign that the aim of scientists will no longer be so predominantly, as hitherto, a flight from the visible and from the practical work of men into the realm of pure thought, a sign that the observation of nature in all its splendor will again be considered intellectually satisfying and a joy of scientists, as it always has been to naive human realists

The whale is the greatest individual form of existence, of life in nature; one blue whale may weigh as much and more than a thousand men. The whale, therefore, represents the greatest contrast to the invisible particles which for many years have so greatly absorbed the interest of scientists On the other hand, the activities of man in whaling are interesting not only from a commercial point of view, but as parables of general problems of the greatest importance in modern human societies.

The particular aim of this lecture will be to discuss analogies or correlations which present themselves to scientific thought in the synoptic view of the life of the populations of whales and the exploitation of the stock of whales.

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[1] A paper delivered at the Tercentenary Conference of Arts and Sciences at Harvard University, September 8, 1936.

(1) Differentiation

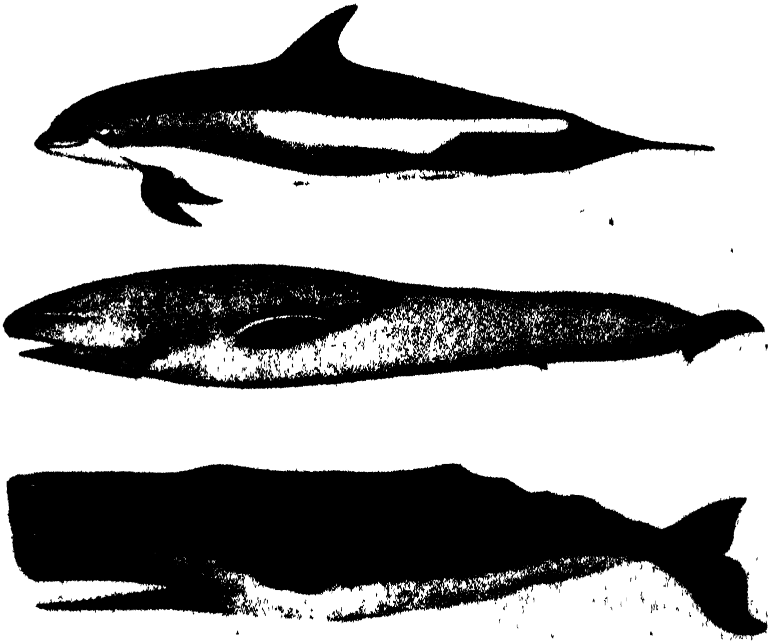
The first and most fundamental analogy between nature and human activities is the parallel of principles which nature applies in her creation of species by differentiation of structures and functions and which man must follow by division of labor in all his enterprise

This parallel, however, has merely a superficial importance if the differentiation into species or the organization of work by division of labor can not be correlated with certain definite factors which guide the events in a special direction. In biology this synthetical process is called the adaptation to the external conditions of life; in sociology, the adjustment of work to technical and social necessities.

If we remember how difficult it is to make out the details of the organization of the enormous bodies of the whales, and if we remember how scarce the material at the disposal of scientists was in former days, it must be considered a remarkable achievement that the Danish biologist Eschricht as early as in 1846 was able to see the correlation between the specific forms of whales and their adaptation to the different sources of wealth and means of subsistence in the ocean. So he distinguished four biological groups of whales. those which lived on fish, on warm-blooded animals, on crustacea of many kinds and sizes and lastly on cuttlefish.

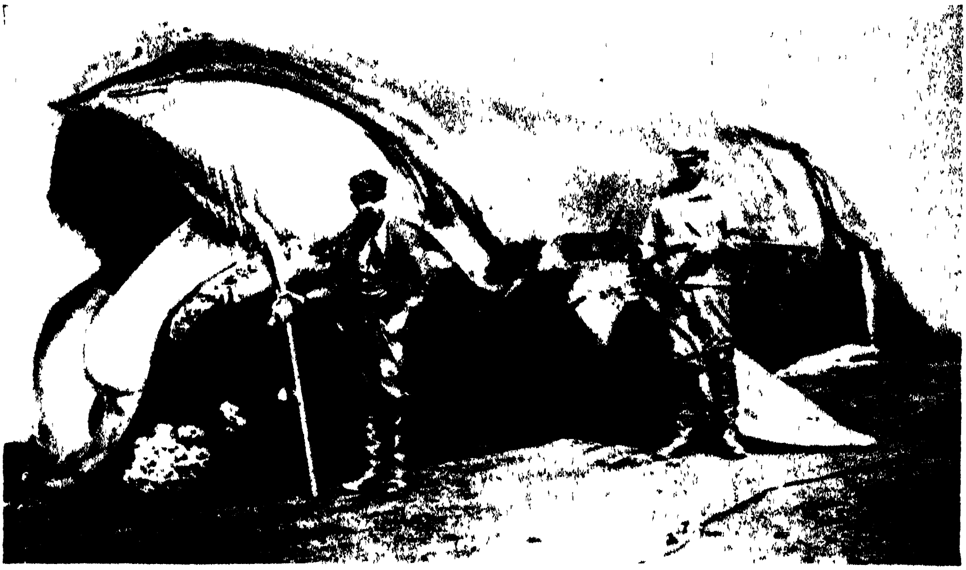
In this way we realize that each type of animal reflects the potentialities of development afforded by the sea itself Knowledge of the whales of the past even enables us to understand the conditions which existed in the ocean in bygone days. A speculative branch of science has actually constructed evolutionary series by which these extinct ancestors are linked up with their modern descendants.

In the coastal seas—off the shores where the ancestors of the whales lived—there were shoals of all kinds of fish,



THREE COMMON WHALES

Top: Delphinus acutus photographed in the Bergen Museum. *Middle:* The Blue whale, *Balaenoptera musculus.* From G. O. Sars. *Bottom:* The Sperm whale or cachalot.



Brun Phot.

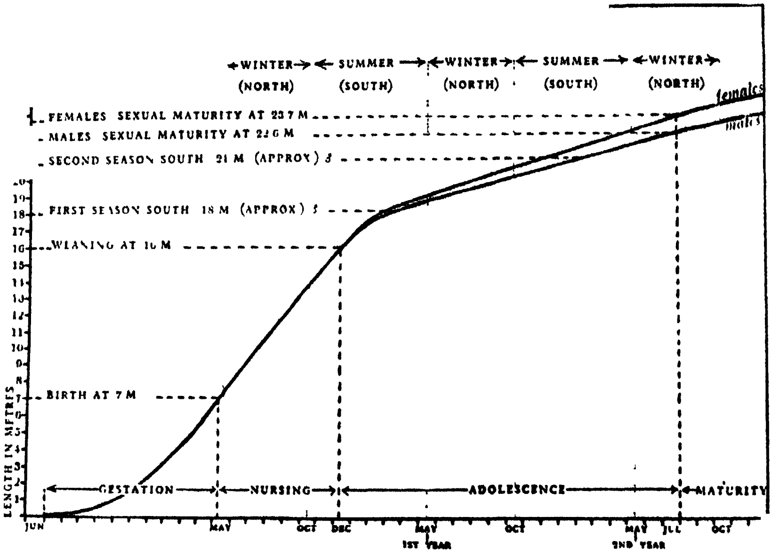
THE ANTARCTIC RIGHT WHALE, *BALAENA AUSTRALIS*.

equal in size to our cod or salmon These were the fish which tempted the land animals to begin hunting in the sea and turned them into fast swimmers and clever fish-catchers. Nowadays the coastal seas support a great many different kinds of whales, the most numerous groups being the dolphins. These are typical fish-eaters

But the coastal seas contain other forms of wealth; small fish in such quantities that, taken in bulk, they leave the larger kinds far behind There are the caplins, herrings, sardines and many other species. And then there are altogether different types of animals—crustacea of innumerable varieties: minute species measuring a few millimeters, which are known as red copepods, and larger sorts, about an inch long, which our fishermen call "krill."

A whale built like a dolphin, with powerful many-toothed jaws, would never survive if it had to live by catching all these little creatures one by one. But common to the life history of all these small species is the peculiarity that they can be caught in a net or bag. Nature made a similar technical invention when she created the grid of the whalebone whales. Of these there are two groups. First, there are the clumsy right whales (genus *Balaena*), like the Nordcaper and the Greenland whale, which skim the sea. The body of the whale pushes as it were its huge mouth through the water, which filters through the high grid of long whalebones, while the small creatures are retained. Then there are the strong, rapid swimmers—the finner whales (genus *Balaenoptera*), which "play," as the whalers call it. No sooner do these whales catch sight of a patch of food than they are upon it in a flash: they take a huge mouthful, say several barrels full, of minute organisms, and then with their powerful tongues squeeze out the water through the natural filter formed by their short whale-bones.

Among the genus *Balaenoptera* nature reaches the greatest units, individual units in existence. The muscles of one blue whale may weigh over 56 tons, its blubber 26, the bones 23, the tongue more than 3 tons and the heart 600 kilos or 1,200 pounds. A new-born blue whale



Mackintosh and Wheeler

THE GROWTH OF THE BLUE WHALE

has a length of 7 meters or 21 feet and weighs 2 tons or as much as 20 men; 7 months later it reaches a length of 16 meters or 48 feet, 12 months later 23 meters or 69 feet. In the first seven months the whale puts on a weight of 21 tons or 100 kilos or 200 pounds in 24 hours. If a blue whale puts on 10 knots speed it develops about 47 horse-powers. For hours on end I have watched my friends the whalers trying unsuccessfully to overtake a blue whale in the Antarctic waters. Hour after hour the impatient gunner would call for full speed, but though he could steam at 13 or 14 knots he often had to give up, while I felt a thoroughly unbusinesslike admiration for the powers of the whale and marveled at the wonderful machinery that nature has constructed out of flesh and blood.

The first whalebone whales must have chiefly preyed upon small fish, which still play an important part in the diet of certain species, such as the humpback and the finner As time went on, however, the ocean crustacea acquired increasing importance. And it became increasingly necessary for the whalebone whales to adapt their habits closely to the habits and habitats (areas of distribution) of the animals upon which they lived. If, therefore, we would understand the habits of the whale, we must make ourselves fully acquainted with the life-history of all these animals, which serve as their food.

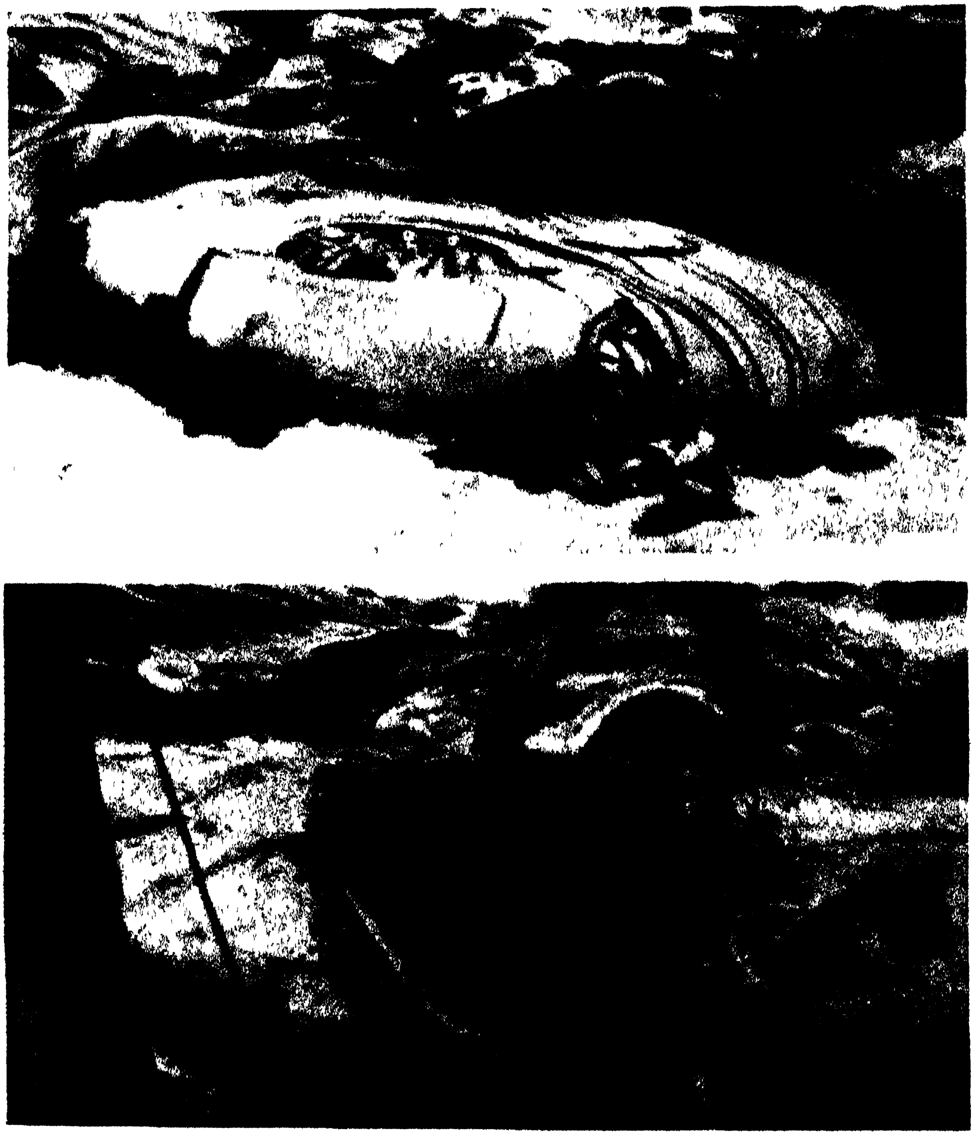
If we fish with a tow-net in the coastal waters of the Norwegian Sea in winter-time, the resulting catch will be very meager. Tons of water may be filtered without finding more than a few surviving specimens of small crustacea, and the only place where a few scattered krill may be met with is the layer close to the bottom in the fjords and on the coastal banks. In spring, on the contrary, when the sunlight calls forth a rich growth of plants, red copepods appear in such immense quantities that they actually make large patches of red on the sea. Later on in the summer there are swarms of krill These rise from the bottom layers of water in order to spawn their tiny eggs, which look like minute glass globes, on the surface of the sea.

It is only at such times, when the red copepods, krill or small fishes are present in dense masses, that the whalebone whale can catch enough food to satisfy its enormous requirements. Whaling operations off the coast of Norway have furnished ample evidence of the connection or correlation existing between the simultaneous appearance of "food animals" and whales. In the north, off the coast of Finmark, several annually recurrent migrations of whales have been observed. Thus in spring (April) the fin whale (*Balaenoptera physalus*) made its appearance exactly at the same time as the vast spawning shoals of a small salmonid, the caplin or "lodde," as our Norwegian fishermen call it (*Mallotus villosus*), arrived on the coast As soon as the shoals of fishes disappeared, the whales likewise took their departure. Later on in the year, at mid-summer, when an arctic crustacean, a krill (*Thysanoessa inermis*) swarmed in these waters, the big blue whale arrived on the spot for the brief spawning period of this krill Farther to the south, off the coast of More (near the Romsdal fjord), spring is the spawning time of the boreal herring, and also of the arctic krill (*Thysanoessa inermis*), which in the arctic north does not swarm before the summer. The fin whales, however, have accommodated their habits to the spawning periods of these animals. In Finmark they pursue the caplin shoals, while off Möre they prey on the shoals of herring. That this is so may be seen from the whalers' annotations of the places where the fin whales were caught in spring and from the contents of the stomachs of these whales. In summer not the arctic but the boreal species of krill (*Meganyctiphanes norvegica*) swarms on the slopes of the southern coastal banks. On the spawning grounds of this latter species fin whales are caught whose stomachs are one mass of krill. But the connection between the simultaneous appearance of "food animals" and whales is, perhaps, clearest if we take into account what we know of the sei whale (*Balaenoptera borealis*), which lives on very minute crustacea (the copepods), especially *Calanus finmarchicus.* A curve represents the efflorescence and subsequent diminution of these small crustacea, in close correspondence with the appearance and disappearance of the sei whale. The correspondence shows similar regularity on all the coastal banks of the Norwegian Sea and the North Atlantic It has been found to exist on the slope of the North Sea, the slopes of the Shetlands and Faroe Islands, and off Iceland and Greenland.

This means that the whale must somehow manage to be always in the right place at the right time. How the whales know their away about in the ocean, and how, for instance, they find the slopes of the coastal banks where the krill spawn, is a mystery too deep for mortal man. All that our researches reveal is the connection between the behavior of the animals which serve as food and the arrival and departure of the whales. We can understand, however, how important it must be for the whales to be able to migrate immense distances. At one time the waters of the Norwegian Sea will be richest off Iceland; at another time on the slope of the North Sea bank; or off the Norwegian coastal banks; or—at midsummer—in the Barentz Sea between Finmark and Spitzbergen. The sei whale, which lives mainly on red copepods, must be on the spot wherever the "harvest" is at its height. The finner whale makes for the spawning shoals of spring-herring in winter, and for the spawning swarms of krill on the banks in summer. Thirty years ago harpoons found in whales caught off the coast of Finmark were traced to the whaling industry off the northeast coast of America.

Great, however, as are the distances covered by the whales, their migrations are none the less subject to definite laws and limitations. In these laws and limitations we see again a close connection between the natural conditions and the animals' lives.

No whalebone whale could survive in those immense vasts of the world ocean



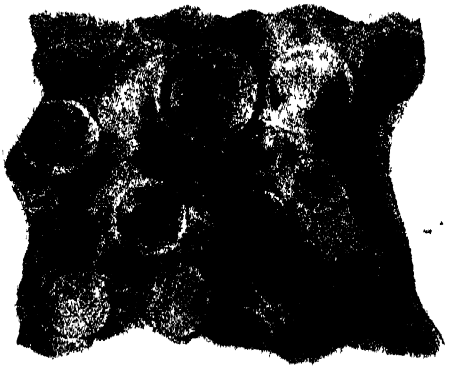
STOMACH CONTENT OF WHALES
Upper: STOMACH OF THE FIN WHALE CONTAINING HERRINGS. *Lower*: STOMACH OF A WHALE CONTAINING KRILL.

where uniform tropical temperatures prevail all the year round. And the reason is evident at once, if we tow a net in such seas. The forms of animal life which furnish the nutriment of a whalebone whale are only present in very scanty numbers in the clear, transparent blue water of the ocean. It is only in the far north or in the highest southern latitudes, that is, in the parts of the sea which form a transition from the warm to the polar regions, that such a profusion of life develops in the water during the summer. At the present time the science known as general biological oceanography is making strenuous efforts to lay bare the causes of this complex distribution of the riches of the ocean in so many different parts of it. The key to the riddle has now been found, and the investigators are now busily engaged in demonstrating all the details of the solution Only in those parts of the sea where the fluctuations of the seasons play a decisive rôle do substances, similar in chemical composition to the manure used in agriculture, rise from the depths to the surface. These stores of nutriment from the depths are responsible for the enormous growth in spring, when the sun returns after the long winter. Biologically, the chief interest naturally attaches to one characteristic feature of the economy of the ocean. This is the fundamental fact that the same natural conditions with the same rich supplies of nutriment for the development of life recur annually in the transitional layers bordering on the polar seas in the south and north; and moreover that both areas, separated though they are by the insurmountable barrier of the tropical seas, foster the same or very closely related organisms, from plants of the simplest structure to the highly developed and complex whales

In the arctic boreal zone, then, the whalebone whales migrate northward as the spring advances, from the Atlantic Ocean to the coastal waters of Norway, the Barentz Sea and Spitzbergen. In the antarctic summer there is a migration of whalebone whales towards the edge of the ice in the south, moving from 50 to 60 and thence to 70 degrees of southern latitude as the summer advances. After that there is a movement in the opposite direction, towards Australia, Africa or South America when autumn and winter set in the southern hemisphere.

A marked feature of the life of the whalebone whales is, therefore, the alternation of superfluity and famine, of the richest fare and lengthy periods of starvation. In these circumstances their life has been preserved by evolving a capacity to store nourishment, *i.e.*, whale oil, in their bodies. This reserve of nutriment is kept in the muscles, bones and layers of blubber under the skin. The stock is laid in in times of plenty, when the layer of blubber swells to many times its former size; later, in the days of famine, it shrinks until, in many places, it is only one inch thick. These reserves give the whales the energy and stamina which enable them to undertake their enormous migrations; and the layer of blubber also makes it possible for these warm-blooded animals to stay about the ice in water, which is often below 1° Centigrade This layer of blubber protects the animal from loss of energy and heat and gives it the necessary strength for its strenuous exertions.

Yet a third great group of supplies in the ocean has been discovered by the whales In all the larger oceanic areas—the Atlantic, Pacific and Indian Oceans—we encounter large herds of immense whales which have found out how to live even in the transparent ocean waters of the tropics They have, in fact, discovered something which was unknown until the great oceanographic expeditions of recent years, namely, that the world-ocean has a layer several hundred fathoms below the surface, inhabited by abundant life. Here one can catch, with a trawl or a large net, quantities of big shrimps and small fish which in turn sustain an animal population of huge cuttlefish, including the so-called giant squid with a body which may be as much as ten meters in length and arms up to six meters long. To capture these organisms nature has created a special kind of whale, the cachalot or sperm whale, and its relative the bottlenose. These whales are able to dive to great depths—several hundred fathoms—and seize the big cuttlefish in their vast mouths. The great heads of the cachalots are often covered with sores and marks of the suckers of the giant squid, tangible evidence of



Murray and Hjort
SKIN OF A SPERM WHALE
WITH MARKS FROM A STRUGGLE WITH A GIANT SQUID

battles between the two largest forms of animal life existing to-day. Such fights are everyday occurrences in the depths of the sea.

(2) THE HISTORY OF WHALING

I have dwelt so long with these elementary and important biological facts, because they seem to me as indispensable for the understanding of the material conditions of whaling.

From the knowledge that every species of whale is dependent on certain specific "food-animals" and from the distribution of these food-animals in different parts of the ocean we understand that the word "whaling" must cover quite a number of different industries.

Frank Bullens
A SPERM WHALE CATCHING A GIANT SQUID.

From the interesting history of these whaling industries we may mention three main and all of them very important groups: the catch of the right whales, of the cachalot or sperm whales and last the modern catch of fin whales.

(A) In the northern hemisphere there are or have been two very important species of right whales: the Biscay whale or Nordcaper (*Balaena glacialis*) and the Greenland whale (*Balaena mysticetus*) These two species supplemented each other, in so far as the northern limit of distribution of the Biscay whale corresponded with the southern limit of the Greenland whale. The latter was a really "arctic" species, the former may be called a boreal species. Perhaps did their area of distribution coincide with different food-animals (species of krill, the arctic *Thysanoessa* and the boreal *Meganyctiphanes*). In the Antarctic Sea there is only one right whale (*Balaena australis*) which seems to correspond very closely, in its form and boreal distribution, to the Biscay whale.

G. O Sars
THE ANTARCTIC KRILL, *EUPHAUSIA SUPERBA*.

The history of whaling as a big industry and as a real exploitation of the life of the high seas had its origin as early as the eleventh century with the catch of the Biscay whale in the Gulf of Biscay, where there lived, even in these early times, a relatively dense population and where daring fishermen made the great discovery that it was not so dangerous after all to attack the large right whales swarming in the bay, even from small and primitive boats.

Since this modest beginning the Nordcaper has been hunted over the great area from the Bay of Biscay to north of Norway and from Newfoundland to the coast and bays of New England, where there in Cape Cod Bay in one day (1700) were killed 29 whales

But as early as about the year 1600 the pursuit of the Greenland whale overshadowed the catch of the Biscay whale in the North Atlantic. It started in the bays of Spitzbergen, transplanted itself along the border of the ice over Jan Mayen to Denmark and Davis Straits and a hundred years ago to the Pacific, where both the important species of right whales played a great rôle in the whaling of these waters.

In the Antarctic there is no species related to the Greenland whale, but the so-called southern right whale (*Balaena australis*) may be considered as identical or very nearly allied to the Biscay whale Like this one it has a "boreal" distribution Great fleets pursued it a hundred years ago off the south sea islands, Australia, Tasmania, Kerguelen, the Crozet, St Paul and Amsterdam

(B) Sperm whaling appears to have commenced on the New England coast about 1712 and spread rapidly all over the tropical and subtropical parts of the Atlantic About 1790 the first spermhunter sailed round Cape Horn into the Pacific. From this time sperm-whaling belonged to all the great oceans The industry reached its height in 1837. The American fleet consisted in 1846 of no less than 729 ships, all whalers, the majority doing sperm-whaling To Dr. Townsend, of New York, we owe the most valuable and brilliant charts of the fields of operation of this fleet. The study of these charts may lead to the most important discoveries concerning the wealth of the oceans and the migrations of whales.

(C) Both of these modes of hunting were done in sailing vessels. In their open rowing boats the intrepid whalers assailed their vast antagonists with small spears and harpoons. The whale was flensed alongside of the ship, and the blubber usually stored on board until it could be dealt with on land. The rest of the carcass was returned to the sea This technique could not be employed in hunting the swift, shy and intelligent finner whales. As long as sailing vessels and rowing boats represented the technique of their human enemies on the high seas, the stock of finner whales enjoyed a perpetual close season.

The invention by Svend Foyn of the technique of steamships, guns and explosive shells meant an entirely new departure in whaling The catch of the fin whales by means of this technique had a very similar course as that of the right whale and sperm whale industries. The whalers moved from one ground to another· from Finmark to Iceland, the Faroe Islands, Ireland, Newfoundland, the coast of Spain and Portugal, in fact, all over the boreal area of the North Atlantic.

Finally they had to move from the North Atlantic area to the South Atlantic, where nature provides the same whales, the same animal food and the same conditions of the sea. The history of all the three main groups of whaling teaches us, therefore, the same course of events: a rapid expansion in all from a starting point to the whole area of distribution of the species and then a rather rapid decline or cessation of the specific whaling activities.

We will now confine our attention to the general conclusions which seem to follow from the study of these important events and more especially consider the last form of whaling, the catch of fin whales, because we in this case are in possession of better and more reliable statistics.

(8) CONCLUSIONS

In the first place we must ask: What is the explanation of the general geo-

Dakin

CATCH OF THE RIGHT WHALE FROM OPEN BOATS
"THE FINAL FLURRY" FROM THE ORIGINAL PAINTING BY O. W. BRIERLY, IN THE NATIONAL ART GALLERY, SYDNEY.

graphical expansion so characteristic in all the different industries? Nowhere has whaling succeeded in establishing a permanent equilibrium or a stable industry in a given definite area To begin with, there has in all cases been a rapid increase until a turning-point was reached, after which there always was an equally rapid decrease ending in a complete stoppage An indication that this development is taking place is the transfer of whaling expeditions from one whaling ground to another That this transfer is not to be considered as an emigration of the whales from one area to another seems perfectly clear, if we consider not only the total number of whales caught in a given area, but also the number of whales per catcher The statistics from the catches of fin whales off the coasts of Spain and Portugal illustrates the fact that the number of whales per boat reached its maximum several years before the total catch did so. In other words, the continued rise in the total number was only rendered possible by the use of increased material, *i.e.*, a larger number of catchers, with the result that the comparatively limited stock perished within a few years. This is, therefore, the general explanation of the main characteristics in the history of all the different whaling industries. The efficiency and the magnitude of whaling operations must not be indefinitely increased but kept at a level corresponding to the reproductive abilities of the stock of whales, if whaling shall ever be made a lasting human activity. Because the stock of whales, *i.e.*, its number of individuals can never be known, the catch, the average catch of the individual unit will have to be considered as the most sensitive barometer of the status of the industry.

From this point of view the Norwegian whalers themselves very early in the history of the Antarctic whaling decided to organize a detailed collection of statistics. Great credit is due to Mr. Sigurd Risting, secretary to the Whalers' Association for a long period of years, for the establishment of this statistical work. At a later date the government's administration (Hvalrådet) succeeded in extending this work to a statistical service built on day-books from all the expeditions whaling in the Antarctic. This organization has had much assistance from the *Discovery* committee and the valuable work by the *Discovery* expedition under the leadership of Dr. Stanley Kemp It is therefore now possible to ascertain all the most important facts from the great antarctic whaling. Date and locality of capture, species, sex, length, is reported for each individual whale. Information concerning the reproduction of the stock and the yield of the industrial production is also available in each individual enterprise

The analysis of this large material, which for every season is published in our reports, will in future form the basis of the history of this industry, and at the same time give valuable information for the understanding of the general problem of the fate of all kinds of human enterprise, which is limited by definite magnitude of wealth in nature Time permits me no more than the shortest review of the most important historical events.

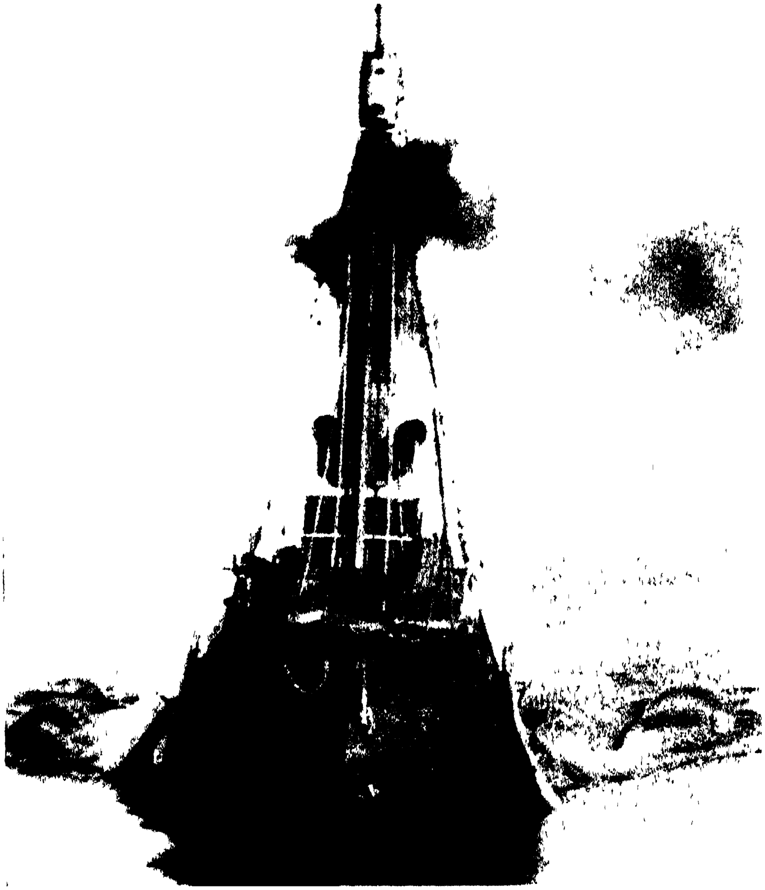
The modern antarctic whaling started at the Island called South Georgia, in the season 1904–1905. The catch consisted then almost entirely of the humpback whales (*Megaptera boops*) one of the smaller fin whales, which very readily lent itself to be caught by the comparatively primitive technique of those days. This species was then represented by enormous herds. "You couldn't miss one of them," an excited gunner said to me in those days. The species supported the catch most liberally for a number of years, but after 1912–13 this stock had obviously been depleted to such an extent that the whalers had to make a change and start catching fin and blue whales as well. This whaling indicated very remarkable fluctuations in the appearance of the two species, which unquestionably live under dissimilar conditions, the fin being a boreal, the blue whale an arctic species. The whalers themselves realized this many years ago. Thus they spoke of "fin whale years" and "blue whale years," and correlated these alternations with the ice-conditions off the island.

In order to understand the further development we must bear in mind the enormous advance that has been made in

WHALING IN THE FJORDS OF SPITZBERGEN

FROM AN OLD DUTCH PAINTING.

the technical equipment of whaling ships. The earliest expeditions to the Antarctic were planned on the same lines, technically speaking, as those operating in the arctic seas. During the first quarter of the century this technique prevailed in connection with the land stations in the South Georgia and South Shetland Islands. An enormous expansion of whaling followed upon the technical inventions which led to the building of floating factories. Ships of ever-increasing size were constructed or reconstructed until they now are equal to great transatlantic liners (over 20,000 or even 30,000 tons) in order to deal with the carcasses of the whales in the most practical way. The whale is now hauled up through a large opening on to the deck, where a complicated mechanism of winches, saws and cranes quickly cuts it up into pieces to be boiled in large boilers of various types.

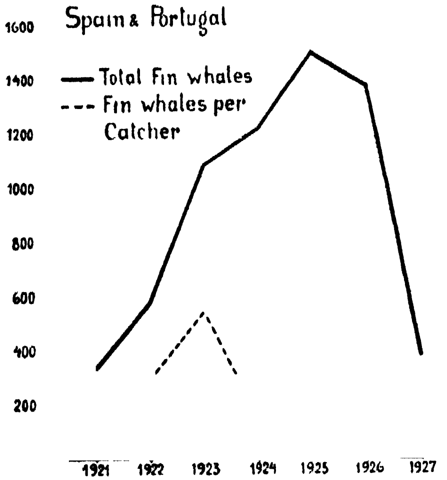


A MODERN CATCHER.

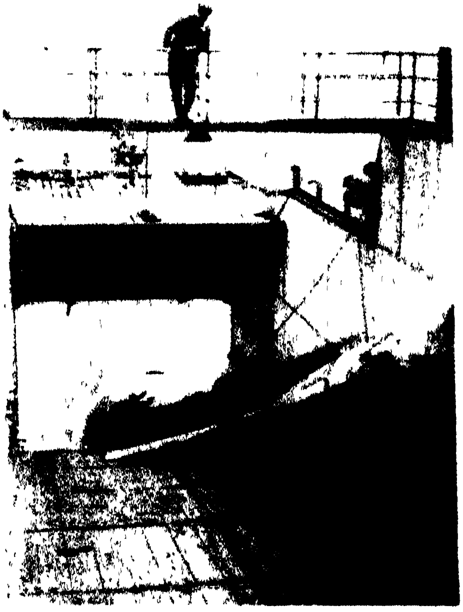
These technical improvements ushered in a new epoch of modern "pelagic" whaling which, like the old right whale and sperm whale industries, operates on the high seas independently of any base on land. In this way antarctic whaling has spread over the whole Atlantic and part of the Pacific Antarctic Seas. For a series of years our statistical data have demonstrated that the whaling always has taken place along the edge of the steadily receding ice, until at the end of the season, it almost reaches the antarctic continent. Everywhere the whales feed exclusively upon the same species of krill, the *Euphausia superba*. During the 36 years from 1886–1904 all the land stations of Finmark caught 17,746 whales, an average of nearly 500 a year, in the Antarctic, where the area covered is immensely wider, the number caught in the season 1930–1931 being more than double the total for the whole period of thirty-six years in Finmark.

For the last thirty years the antarctic whaling has played a great rôle in the life of the population of the southeastern part of Norway, and it is therefore easy to understand that these two questions are being asked and discussed: How long is the whaling going to last and how can we make it last?

We meet in this discussion the old slogan: trust in the general economical principles and in the principle of rationalization! These principles are certainly and very actively at work. The result of this is that at least 50 per cent. more oil is obtained from each whale than was done in the past. Much capital has been spent by the whalers themselves on experiments on new machinery for converting the flesh and bones into guano or into food for man and beast. But it is obvious that these praiseworthy efforts are not enough in themselves to establish an equilibrium between the whaling industry and the animal renewal of the stock, and nothing but an equilibrium will render possible the continued exploitation of the wealth of the seas or prevent a recurrence of the periodic increase in whaling activities, succeeded by a decrease and final stoppage. The more valuable the single whale becomes, the further the extermination of the stock is likely to proceed. The fate of the Greenland whale, which rose to such a value



NUMBER OF FIN WHALES
CAUGHT OFF THE COASTS OF SPAIN AND PORTUGAL



WHALE BEING HAULED ON DECK.

THE MODERN FLOATING FACTORY S. S "VIKINGEN" IN THE HARBOR OF S. GEORGIA.

that one single individual was enough to pay all the expenses of an expedition, is a very striking proof of the thesis that the perfecting of methods of capture and preparation affords no solution of the problem of the continuance of whaling On the contrary, it leads straight to the extirpation of the stock

Whaling is—in other words—a new and extremely illustrative example of the fact that rationalization is no way to avoid the great Malthusian problem of overpopulation—human activity being ruined by its own growth, by the forces that check development and progress, the forces that obey what Malthus termed "the restrictive law of population." Seen in wider perspective, these events in the whaling industry naturally suggest comparisons with the extensive structure of observations and thought built up during the last few decades with a view to a better understanding of the growth of populations under different conditions of life If we compare on the one side the two curves for a growing whaling industry and the catch per boat, on the other side the growth of a colony of bacteria and its rate of growth, we understand that the expansive development, which we sometimes name rationalization, sometimes competition, may further the rate of growth or standard of life of the individual up to a point, from which onwards an increase of the active population destroys the industry and lowers the individual standard of life. Rationalization and competition are ideals which are conceived in a time of expansion, but they become irrational and destructive to the welfare of the population if the harmony or correlation between the wealth of nature and the activities of man are forgotten or lost out of sight.

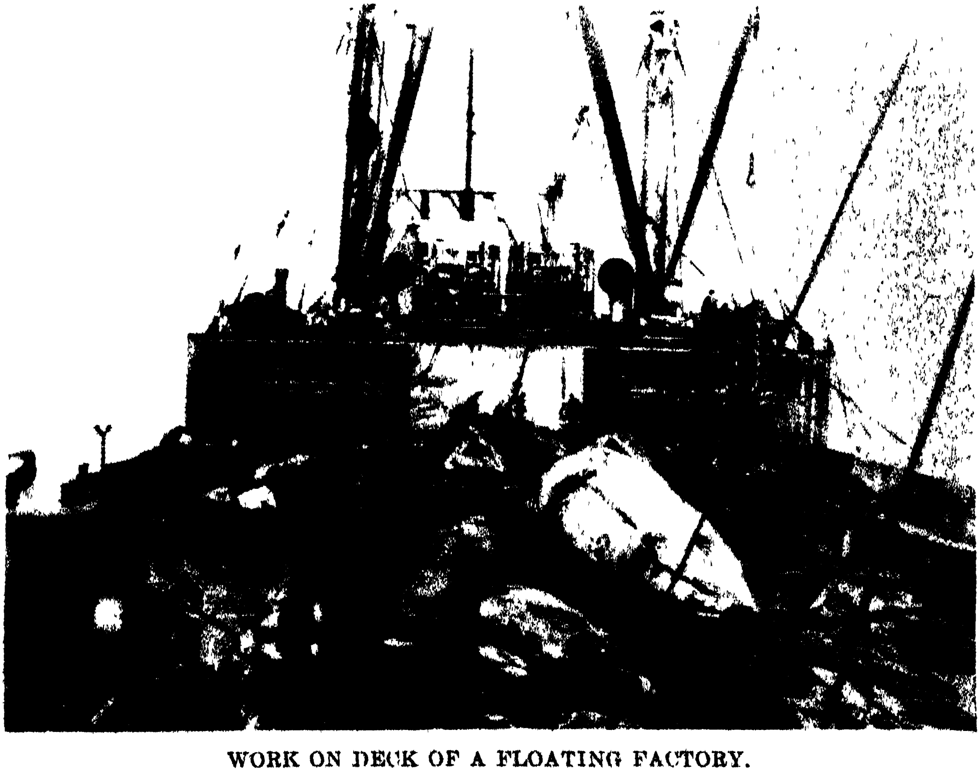
The Norwegian whalers or in any case some of them have been willing to accept these points of view In 1926, when the great expansion of the pelagic whaling started, a committee proposed that the Norwegian government by law should forbid any expansion, any new expedition which had not obtained the permission of the government to go whaling in the Antarctic, on the condition that such an action would meet with an *international* support. In 1927 at a great conference summoned by the French government to Paris this proposal was tentatively advanced by me as well as by a British representative, but we met with a most emphatical refusal from the side of delegates of several countries.

Nevertheless, the Norwegian whalers have for a series of years in coöperation with the administration tried to establish a constant equilibrium in the catch, and the catch has in this way been kept practically constant at a quantity of some 2. 4 million barrels a year from the year 1932–1933 until now The means by which this result was obtained have partly been voluntary production agreements or quotas allotted to each expedition, partly a time-limitation of the whaling season, for the last season to three and a half months

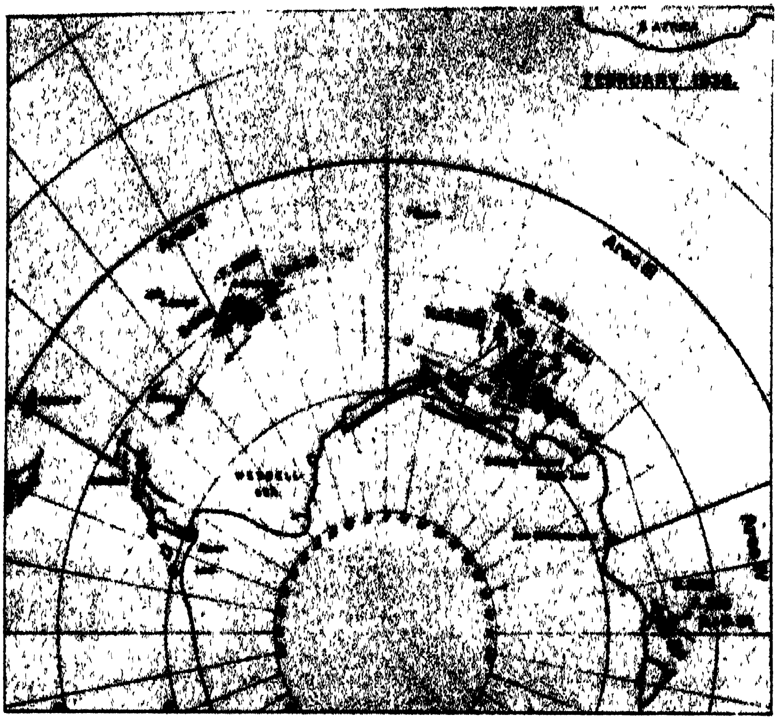
The statistics show that the catch under these conditions has been able to maintain a paying industry if not at a standard of life so high as it was some years ago The statistics show signs of a decrease of the stock of blue whales, the most valuable species, and that the production has only been maintained by an increased catch of the other, previously neglected species, the fin whale.

The future is therefore certainly full of anxieties. And these anxieties are of the kind which we all know from other expanding international industries. No legislation by the Norwegian government, no self-restriction on the part of the Norwegian whalers can maintain an equilibrium of an industry which assumes an international character.

In all industries there seem to have been two different periods of development. In the beginning the new idea of division of labor creates a long series of discoveries, inventions, all taking the form of an increasing number of plans of division of labor. Later on the original idea seems to lose its fertility The increase of the number of people taking part of the work is then mostly due to imitation and the application of power or force of conquering the other man's place in the sun Competition takes at that



WORK ON DECK OF A FLOATING FACTORY.



CATCH OF WHALES IN THE ANTARCTIC
AN EXAMPLE FROM OUR STATISTICS.

stage the form of nationalism, of barriers or national monopoly at the home market while at the same time demanding the retaining of advantages which a liberal world had created.

This has been the fate of Europe, of the old civilized world which once had entered into an international division of labor and tended towards a great common community but now seems to dissolve itself into a system of antagonistic autarchies Very little hope can under these circumstances be entertained of an international equilibrium of any industry on the free seas, where no organization can be created for an optimum population and an optimum catch.

We must therefore expect either that the industry will establish an equilibrium at a low level determined by the minimum standard of life for the whalers, or that there will be fluctuating periods of successful and unsuccessful whaling corresponding to a slow and incomplete recovery of the stock, similar to what has been seen both in the stock of right whales and of fin whales in areas where the population of whales once were abundant and the industry flourishing.

Is this prospect a parable of the modern international civilization or will ever an idea be discovered not only for the individual but also for an international division of labor?

The fate of the warnings of biology may in our days remind us of that of Cassandra in the Greek tragedy. But the story of past events in the living world may in days to come act its part in the conscious life of society.

CHIMU ARCHEOLOGY

THE ARCHEOLOGY OF THE NORTH COAST OF PERU

By Dr. WENDELL C. BENNETT

ASSISTANT CURATOR OF ANTHROPOLOGY, THE AMERICAN MUSEUM OF NATURAL HISTORY

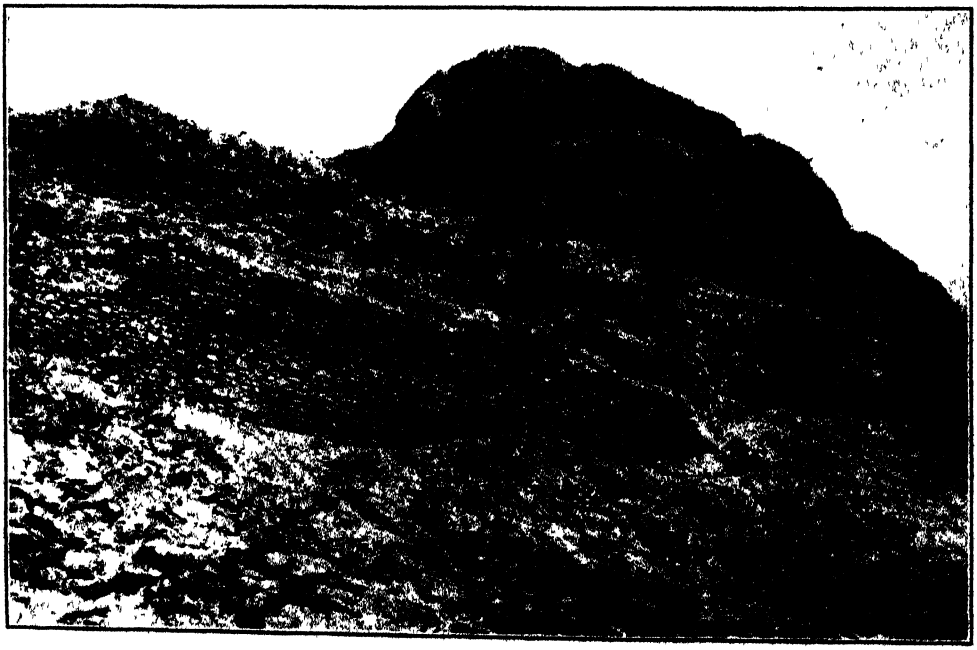
IT was only a hundred years before the coming of the Spaniards that the Incas were sufficiently consolidated and powerful to attack the kingdom of the Chimus on the north coast of Peru Under the Inca, Pachacutec, 40,000 highland soldiers and auxiliaries from the coast were assembled for the conquest Even so, according to Philip A Means, the submission of the Chimus was more the result of fatalistic foresight on the part of their councilors than fear of a superior force of arms. The Chimus themselves had built up a vast empire covering the north coast of Peru from Paramonga to Piura. The great expansion occurred during the late period of the Chimu civilizations, known archeologically as the Late Chimu Several civilizations preceded the Late Chimu on the north Peru coast, which were intensively developed in their own sections, although more limited in territorial distribution

Geographically, the north coast archeological region extends for over four hundred miles along the coast and includes twelve important valleys. From south to north these are Huarmey, Casma. Nepeña, Santa, Viru, Moche, Chicama, Jequetepeque, Saña, Lambayeque, Piura and Chira. In general, the northernmost valleys are larger and better supplied with water. However, only in the Piura and Chira valleys is agriculture able to depend on direct rainfall, while in the other valleys irrigation is required. The cultivation problem in most of the valleys is not one of scarcity of land, but water supply. Although the rivers of seven of the above-named valleys originate in the continental watershed, the supply of water is not constant In the mountain rainy season, which lasts from January to April, the rivers are apt to be torrential, while during the rest of the year the streams may dry up completely. Between river valleys, and in parts of the unirrigated sections of the valleys themselves, desert conditions prevail A rough average of 25 to 30 miles of desert separates each valley from its neighbor, and the greatest single stretch of about 100 miles is the desert of Sechura, between Lambayeque and Piura. Compared with the vast stretches of desert and mountain, the coastal valleys are mere ribbon strips One is particularly impressed by this in flying along the coast When the trip from valley to valley is made by car, one has a real appreciation of the inter-valley desert areas as factors of isolation In the northern part of Peru the Andes are not far from the Pacific Coast and spurs and foothills reach the ocean itself. Only in the lower part of a valley is the flood plain of sufficient width to support intensive agriculture. The upper part of the valley passes through narrow gorges which leave only small pockets of flat land for agriculture. The country surrounding the valleys is rugged. The coastal valleys are not only separated by desert stretches but by mountain ridges as well.

This brief sketch of the topography is necessary for an understanding of the archeology. One is impressed by the fact that most of the Peruvian valleys present little enticement to a people without both agriculture and a knowledge of irrigation. Fishing groups could live along the coast, but fishing peoples seldom develop high civilizations. Only in the northernmost valleys, Lambayeque, Piura and Chira, where the river flow is more permanent, the flood plains wider and direct rainfall more frequent, might the situation be different. In that section, relatively close to the Equator, sufficient forestation and animal life may have existed to attract and support a hunting people, or at least agriculturists with or without knowledge of irrigation. I mention this contrast between the far north and the rest of the coast in anticipation of the archeological analysis which presents some disturbing problems.

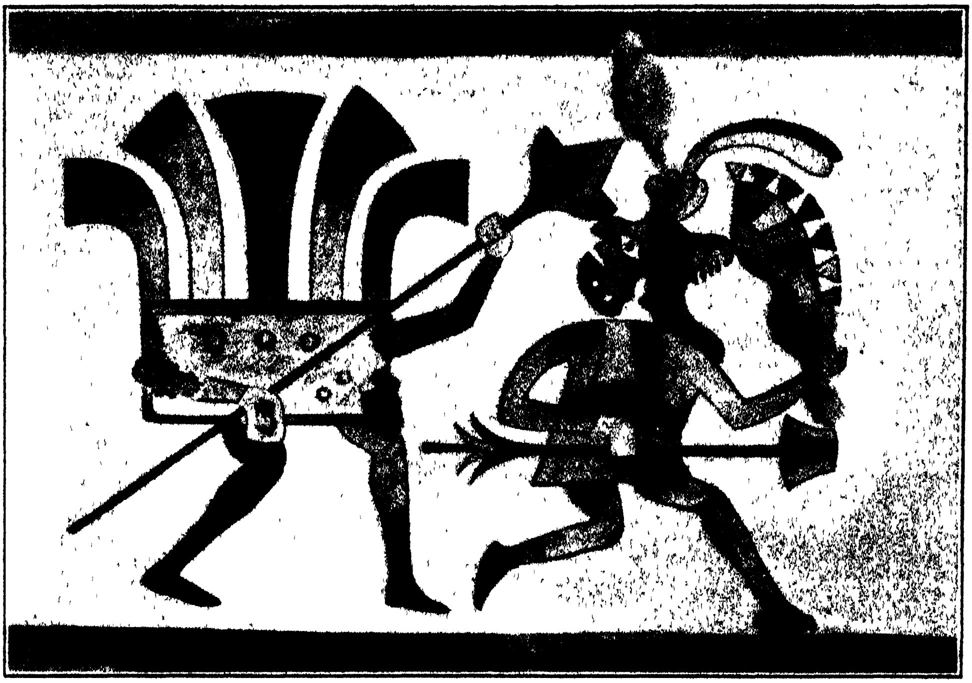
PRE-CIVILIZATION PERIOD

Archeological work has so far presented practically no information about the first inhabitants of the north coast. Remains of relatively primitive fishing populations have been found at Ancon and Supe, just south of this area. However, in spite of the primitive nature of some of this material, there is no proof that it is really older than the remains of some of the higher civilizations of the coast. Fishing hamlets still exist along most of the Peruvian coast, and the life of the fisher is a hard one. Poverty may easily be confused with primitiveness because a poor community might leave few remains for the archeologist. To my knowledge, nothing has been found of great antiquity which is undisputed. No fossil man, no associations with extinct fauna, no artifact deposits in old geological strata and, for that matter, no accumulated refuse deposits of great stratigraphic depth have been reported and confirmed. In other words, evidence either of the development of civilization, or of primitive stages, has not been found on the north coast of Peru up to this time. The oldest civilization on this coast at present is the Early Chimu. To speak of this as the "dawn" would be erroneous. Rather, we might say that the full sun of the Early Chimu suddenly



EARLY CHIMU PYRAMID

OF ADOBES ON PILED STONE FOUNDATION AT EL CASTILLO IN VIRU VALLEY.



DETAIL OF THE EARLY CHIMU FRESCO
AT THE MOON TEMPLE, MOCHE, AFTER A WATER-COLOR REPRODUCTION.

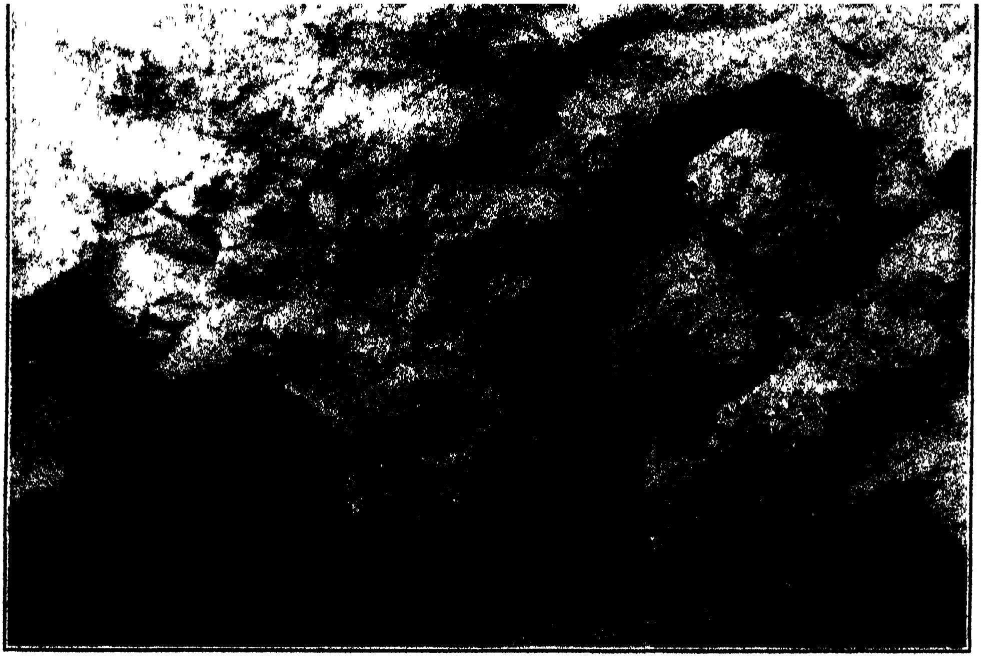
shone on this north coast. Far from being primitive, the Early Chimu or Muchic civilization is one of the most advanced in Peru.

EARLY CHIMU PERIOD

Geographically, the Early Chimu civilization is centered in the Chicama, Moche and Viru valleys. Extensions are found in Jequetepeque Valley to the north, in Santa and perhaps Nepeña to the south, but with less concentration. Further extension along the coast is dubious, although certain similarities may be found in the northern highland region, especially in the Callejón de Huaylas. Means dates the Early Chimu as something B.C. to about 500 A.D. and other authors have more or less accepted this dating. In any case, the Early Chimu can be isolated stratigraphically and typologically as older than other north coast civilizations.

Many large pyramids are attributed to the Early Chimu period. They are identified at some sites (such as El Brujo in Chicama Valley) by their stratigraphic position under secondary buildings of later periods. At other sites the arabesques and mural paintings on the walls are Early Chimu in style, and associated artifacts are likewise consistent. The pyramids are built of adobes, conventionally rectangular in shape and mold made. Adobes of other shapes are also associated with Early Chimu and suggest a possible sequence of types. I have seen adobes of rectangular shape superimposed on hemispherical and on conical shapes. The pyramids themselves are usually high, rectangular, step-sided piles of adobes, and represent some of the largest single structures on the north coast of Peru.

The Pyramids of the Sun and of the Moon at Moche are typical of the Early Chimu structures. Squier gives the measurements of the Sun pyramid as 800



EARLY CHIMU GRAVE IN CHICAMA VALLEY
SHOWING THE NICHES IN THE WALLS OF THE TOMB.

EARLY CHIMU PORTRAIT
FROM VIRU VALLEY.

feet in length, 470 feet in width and about 200 feet in height. It is formed of a great central core of solid adobes with facing layers of adobes around it, forming seven to nine steps. It is an imposing structure, commanding a view of the Moche valley flats. Behind the Sun temple part way up a hill is the Moon temple, also of solid adobes. Painted walls at the Moon temple represent scenes of mythical figures in black, white, red, yellow, light blue, pink and brown. The cemeteries which surround the temples have furnished great quantities of Early Chimu pottery. Early Chimu cemeteries are also found without pyramid associations. Burials are usually in extended positions, in prepared tombs. The rectangular, adobe-lined and covered tombs have niches in their walls in which bowls were placed.

The Early Chimu pottery is characterized by realistic modeling and painted scenes. Jars in the form of modeled heads are so excellently made that they

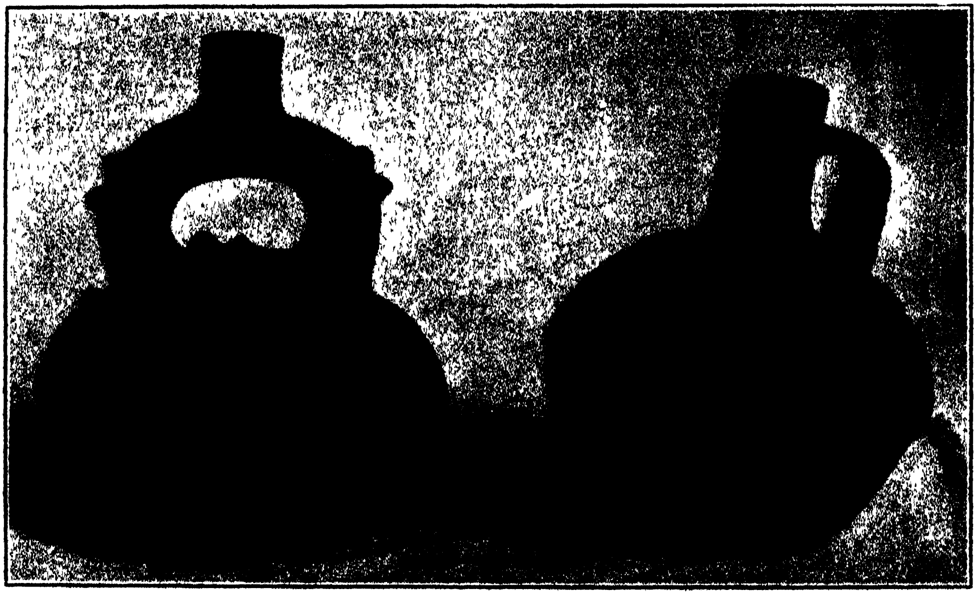
VESSELS DECORATED WITH "NEGATIVE" DESIGN.
MIDDLE CHIMU WHISTLING JAR, AND OWL JAR FROM VIRU VALLEY.

are reasonably called "portrait jars." Other jars are modeled to represent houses and temples. Small square houses with peaked roofs are typical, which seems strange for a region which experiences direct rain in any quantity about once in every thirty-five years. In the painted scenes are represented deer hunting, battles, fishing, dancing, weaving and many other aspects of life. In fact, a careful analysis of the pottery designs is in reality an ethnography of the Early Chimu peoples.

The archeologist is tempted to diverge into the field of art in his study of the Early Chimu pottery. As an artistic achievement the ceramics of the Early Chimu period are outstanding in Peru and, for that matter, in America. However, from the point of view of the chronology of north coast civilizations, the varied ceramic designs of the Early Chimu period must be treated as a unit. In spite of tremendous collections of this

EARLY CHIMU FIGURE JAR
WITH STIRRUP-SPOUT, VIRU VALLEY.

material in museums there is a dearth of documentary evidence on excavation. The collections made by Dr. Max Uhle at Moche and now in the University of California are exceptions. Still, they do not furnish the basis for subdivisions of the Early Chimu period The range of style and the change of form suggest that phases, at least, of Early Chimu will one day be isolated, but, as yet, no significant work has been published and so the material is still a large, but none the less, single unit.



MIDDLE CHIMU JARS FROM VIRU VALLEY.
THE STIRRUP-SPOUT IS EVIDENCE OF EARLY CHIMU INFLUENCE.

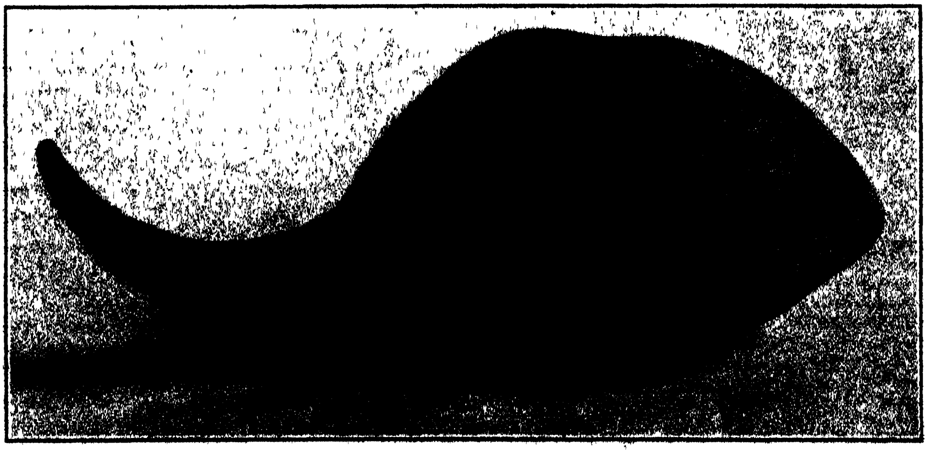
Typical colors of the Early Chimu pottery are red and white, which is quite a contrast to the array of colors used on the wall painting at the Moon temple. A so-called stirrup-spout, composed of two tubes which form an arch and meet in a single tube, is characteristic and is found on modeled heads, figures, animals, birds, reptiles, fruits, vegetables and painted containers of various forms. Other type shapes are a flaring-sided bowl like a flower pot, a conical-handled dipper, a high collar bowl with or without a modeled face on the collar and a tube spout bowl with a round arc handle.

MIDDLE CHIMU

Between the Early Chimu with its realistically decorated pottery and the Late Chimu, which persisted into Inca times, a gap was recognized by most excavators or collectors even before the intermediate stages had been discovered. The contrasts between the two periods are great, in spite of certain basic similarities. In other words, it appears that the Early Chimu civilization went into a period of decline or was supplanted for a time by foreign invaders. The typical Early Chimu disappeared, never to reemerge in the same form, although the influence of its art and certain of its pottery shapes survived to form part of the Late Chimu. Evidence of influence from the south of Peru is undeniable in the Late Chimu pottery, which augments the idea of invasion with or without the accompanying decline of Early Chimu itself.

VESSELS OF THE MIDDLE CHIMU PERIOD FROM VIRU VALLEY.
LEFT: A DOUBLE JAR WITH "NEGATIVE" DESIGN. RIGHT: A FACE-COLLAR PLAIN BOWL.

In my excavations during the first eight months of 1936 in Viru Valley I worked for some time at a site on Carmelo Hacienda. Here, in the pyramids of the Gallinazo group, I found a new type of pottery which showed some influence of Early Chimu, had many distinctive characteristics and was definitely not Late Chimu. In other words, the site, a unit in itself, represents an intermediate period or a Middle Chimu. Four medium-sized pyramids are roughly aligned, but not connected On the platforms of these pyramids are the foundations of old house sites, which furnish house refuse material and a few burials when excavated. Near one pyramid are two small mounds filled with burials. The burials are not in prepared tombs, but are placed directly in the ground, some in a



MIDDLE CHIMU DIPPER DECORATED IN "NEGATIVE" DESIGN,
REPRESENTING A CARRY-OVER SHAPE FROM THE EARLY CHIMU PERIOD FROM VIRU VALLEY.

flexed and some in an extended position. The adobe bricks used in building the pyramids are about the same size and shape as the Early Chimu, but their edges are marked with the impressions of a reed mold

The pottery is inferior to the Early Chimu, but still shows its influence A modeled figure bowl with stirrup-spout is represented as well as other vessels with stirrup-spouts A conical-handled dipper, a high collar jar with modeled face on the collar and various other shapes are clearly related to the Early Chimu. In addition are globular bowls with lugs attached which represent bird heads, wings and tails; bowls with conical spouts connected by round bridges to modeled bird heads; double bowls with modeled figures; and various others which are never found in the Early Chimu. Of more importance is the fact that the typical red and white colors of the Early Chimu are not used on this pottery. Although many bowls are not painted at all, others are decorated with "negative" design. In "negative" painting a design is applied to the bowl in wax or some other dye or paint-resisting material. Then the whole bowl is dipped in black coloring. When it is fired the wax runs off, leaving a design in the base clay color on a black background.

BLACKWARE,
STIRRUP-SPOUT VESSEL OF "CHAVIN" TYPE IN THE NATIONAL MUSEUM OF LIMA.

The presence of negative design as a characteristic of this pottery suggests contact with another region. In the highland part of the Santa Valley is the Callejón de Huaylas. The remains from that section are distinct from the coast materials. Negative painting is characteristic, particularly at the site of Recuay. Shapes similar to some of those which I found in the Middle Chimu site in Viru Valley occur in this highland pottery. In other words, the Viru site seems to represent a migration, or at least a strong influence, from the Recuay-type civilization. This, mixed with a decadent Early Chimu, would account for most of the Viru site material, and the residue might well be attributed to local development, since the four pyramids and the numerous dwelling sites indicate that it was well established there.

The distribution of this Middle Chimu civilization is not accurately known, and, to my knowledge, the Viru site represents its first isolation. If "negative" designed pieces be considered as typifying it, we may note that they have been found in Santa, Viru, Moche and Chicama, or more or less over all the Early Chimu region.

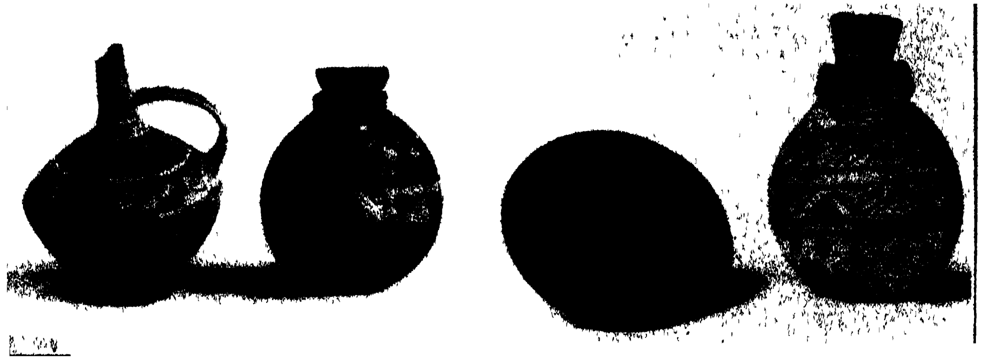
In the highlands, in the general region of the Callejón de Huaylas, is the famed site of Chavín de Huántar, noted for its amazing stone carving. On the coast of Peru, principally in Chicama Valley, have been found polished blackware bowls with thick stirrup-spouts which are decorated with incised designs compar-

LAMBAYEQUE VALLEY POTTERY.
LEFT: INCA POTTERY. RIGHT: "CURSIVE" STYLE VESSEL.

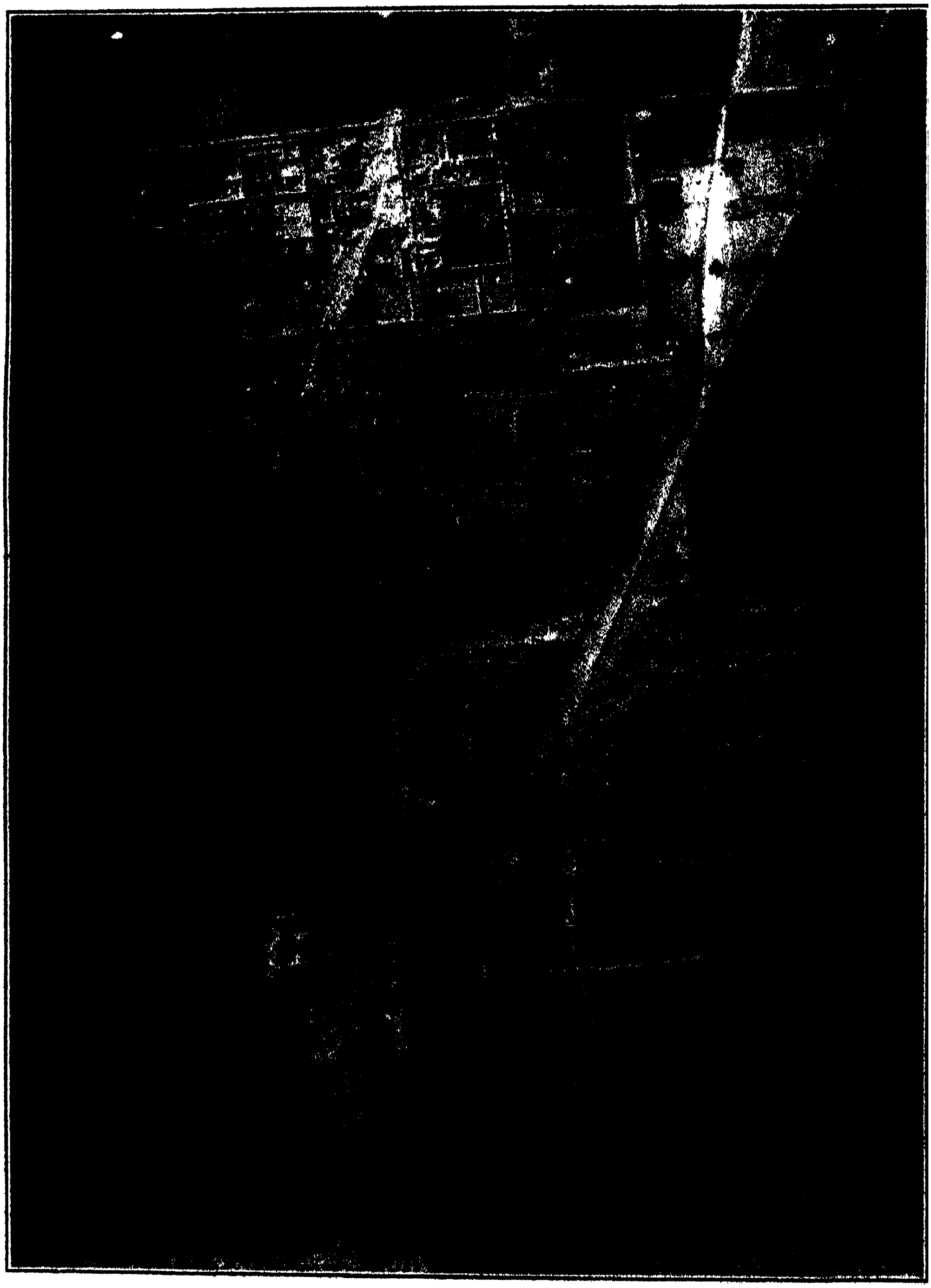
able to the stone carved designs of Chavín. Their position in relation to the Early Chimu is still questionable, and many consider them as belonging to a preceding period. It seems more probable to me that the Chavín stone carving designs were brought in and applied to pottery by the same peoples or influence which created the Middle Chimu of my Viru site.

OTHER MIDDLE PERIODS

The Middle Chimu, just described, represents a recent discovery, but other influences and periods which fall into this interim between the Early and Late Chimu are known from the work of other archeologists. At Pachacamac and other sites on the central coast of Peru, around Lima, one of the earliest periods represented is the Tiahuanaco. The Tiahuanaco site itself is located in the highlands of Bolivia, but the civilization spread to the coast, forming a secondary center on the central coast. From there it spread both to the south and to the north. In the course of this expansion it incorporated many new elements from the civilizations with which it came in contact, notably the Nazca civilization on the south coast, the result of which is really a new style characterized by the use of



POTTERY FROM VIRU VALLEY.
LEFT: BLACK, WHITE, RED POTTERY. RIGHT: A BLACKWARE PLATE AND A BLACK, WHITE, RED FLASK FOUND IN THE SAME GRAVE.



SECTION OF THE CITY OF CHANCHAN, NEAR TRUJILLO, PERU.
LATE CHIMU CITY WITH PYRAMIDS, BUILDINGS, AND COURTS WITHIN WALLED UNITS.

black, white and red design colors for pottery. The excavations of Dr. Uhle, confirmed by the analysis of Dr. Kroeber, isolated graves of this Tiahuanaco-influenced black, white and red pottery at Moche. They demonstrated that this type of pottery occurred after the Early Chimu and before the Late Chimu periods.

In Viru Valley I excavated a mound which represented a habitation site of the Early Chimu period. Intrusive in this site were graves containing pottery of the black, white and red type, and also considerable blackware Shapes and other characteristics serve to demonstrate that the blackware and the black, white and red are contemporaneous at this site and form a unit. In spite of the high percentage of blackware, a Late Chimu characteristic, this grave material is not typical of the Late period. Similar sites have been found elsewhere.

The contact of the black, white and red material from the central coast with the Middle Chimu style already established in the Viru Valley and others, gave rise to a great variety of minor styles. Thus, at the sites of Chanchan and Moche, Kroeber distinguishes a black, white, red; a black, white, red, Recuoid; a cursive; and a cursive tripod. All these styles may never be isolated as separate phases or periods, but they represent the varied strains of influence that interrupted the Early Chimu and brought in the elements known to comprise the Late Chimu.

LATE CHIMU

Out of the complex influences of the Middle periods, together with a revival of the dormant Early Chimu, came the Late Chimu. As a period, it represents a new era of autonomy, with little, if any, influence from outside regions. Characteristic is the emphasis on blackware. Less and less attention is paid to painted design, and the modeled and mold-made pottery is smoked in firing to a rich black color. The stirrup-spout of the Early Chimu period is again used with frequency, but it is roughly rectangular in cross-section instead of being round as before, and at the base is added a small modeled lug in the form of a bird or monkey. Double-spouted vessels are common, brought up the coast with the black, white, red pottery from the Nazca region. Double bowls, generally with whistles, are typical. Most of the forms can be derived from the preceding periods, but there are new elements as well. Burials are flexed, usually in a seated position, in graves rather than prepared tombs.

Starting in the Middle periods and continuing with great concentration in the Late Chimu is a new building era. Great cities are constructed in which pyramids are incorporated but are not distinct units. The great city of Chanchan is typical, covering about eleven square miles with a maze of walls, reservoirs, buildings, temples, gardens and cemeteries Relief arabesques of fine figure designs adorn the walls. The adobes are either small square blocks or long rectangles, and a puddled clay wall, called *tapia,* is also common.

Great pressure for expansion develops in the Late Chimu period. Irrigation projects which open up new tracts of land are carried out successfully. Small quebradas at the edges of valleys are utilized. Furthermore, the expansion includes valleys to the north that were but sparsely settled, if at all, in previous periods. The Late Chimu period concentrates in Lambayeque Valley, where ruins of great size are numerous. The "Purgatorio" city ruin in Lambayeque is in some ways as impressive as Chanchan, although smaller in actual extent. At the time of its maximum expansion, the Late Chimu covered the full four hundred mile stretch of the north coast from Chira and Piura valleys in the north to Paramonga in the south. The great cities in themselves imply a well-integrated social organization, as it has been estimated that about 200,000 people lived in Chanchan alone.

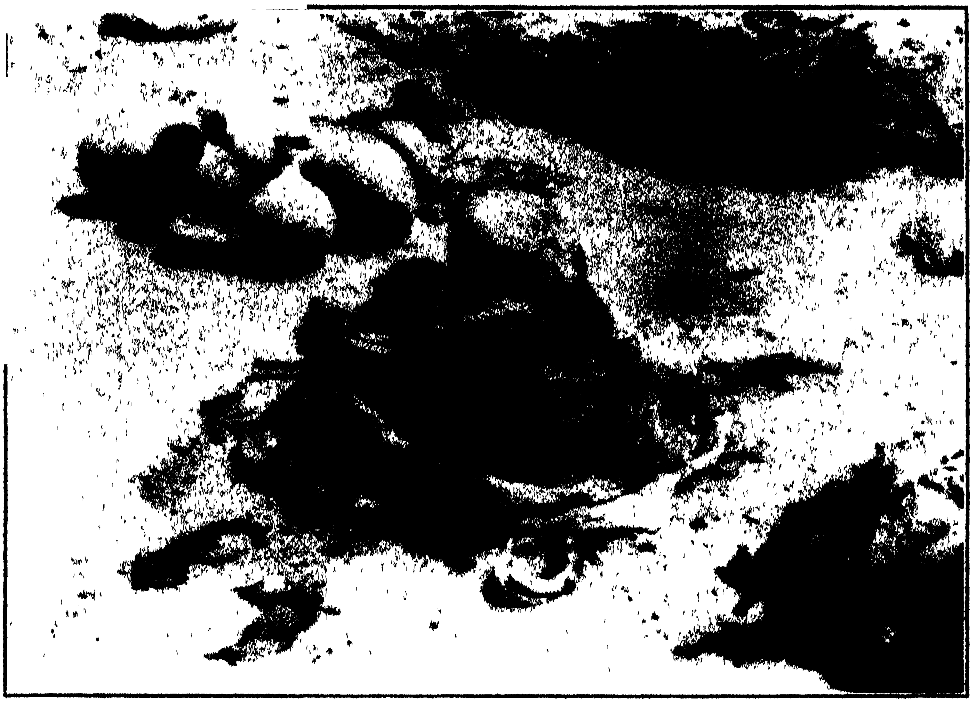
The Late Chimu peoples were conquered by the Incas in the fifteenth century, but little change in materials is noticed. The type ceramics continue more or less the same, with the addition of a few Inca forms The polychrome Inca pottery shapes are copied in the Late Chimu blackware, and in other artifacts slight Inca influence is in evidence

LATE CHIMU WALL ARABESQUE

FROM A TEMPLE AT THE QUINTA ESMERALDAS NEAR TRUJILLO, PERU.

The Late Chimu-Inca civilization continued for some time after the coming of the Spaniards Typical Late Chimu pottery is found with decorations in a Spanish glaze. Textiles made by the Indians with the same materials and the same looms as before incorporate Spanish elements in the design.

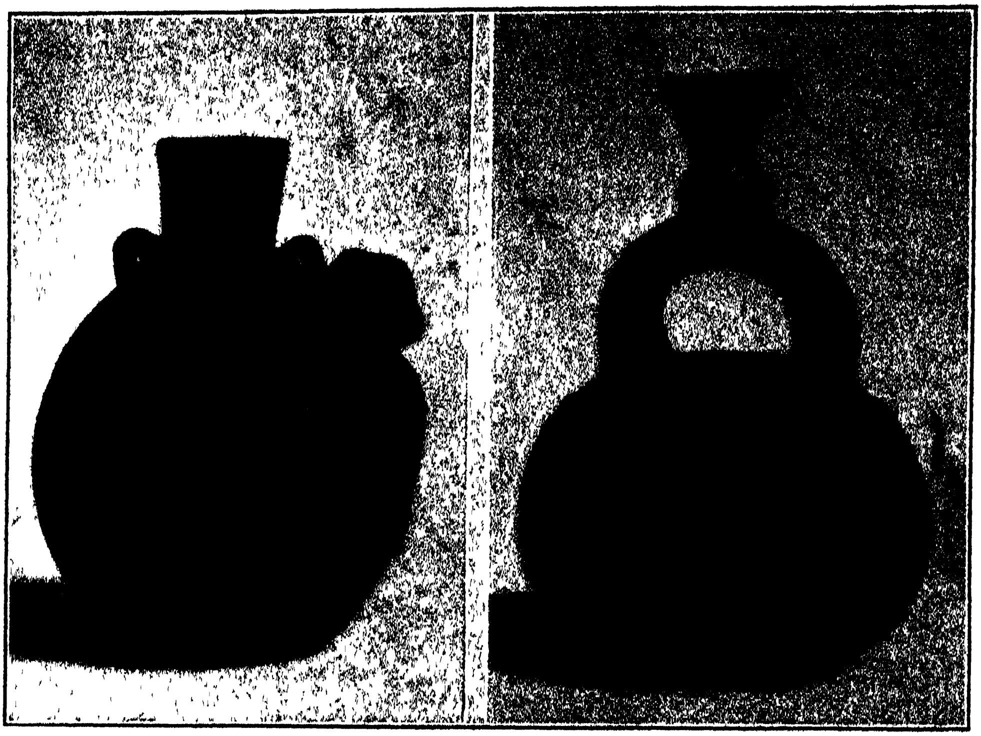
One problem stands out prominently amongst a myriad others in this résumé of major civilization changes on the north coast. Lambayeque and Piura represent two of the most favorable valleys in Peru to-day, from the point of view of extent of land and the abundance of water. That they were also favorable in pre-Spanish times is witnessed by the extensive irrigation systems and the vast number of ruins found there. The ruins, however, represent, at best, the Middle periods and predominantly the Late Chimu and Inca periods. In the vast collections of pottery made in those valleys hardly a piece can be unquestionably identified as Early Chimu. Furthermore, there is no group of pottery which can not be explained as an influence from the south or a local development therefrom. In other words, in two of the finest valleys of the Peruvian coast nothing has appeared which can be called contemporaneous with the Early Chimu of Chicama and Moche valleys. It is, of course, possible that more excavation will reveal new types, but considerable work



LATE CHIMU MUMMY BUNDLE
PARTIALLY UNWRAPPED, WITH THE POTTERY FOUND WITH IT. VIRU VALLEY.

has already been done, especially by local collectors. One explanation is that such fertile and well-watered valleys were so overgrown in Early Chimu times as to support hunting populations and discouraged agricultural expansion until

TWO LATE CHIMU BLACKWARE DOUBLE WHISTLING JARS FROM CHICAMA VALLEY.



LATE CHIMU POTTERY.
LEFT: A BLACKWARE FLASK FROM LAMBAYEQUE. RIGHT: VARIANT TYPE OF BLACKWARE BOWL WITH STIRRUP-SPOUT FROM VIRU VALLEY.

population pressure demanded it. However, the problem remains unsolved. Furthermore, if migrations came from the north and followed down the coast into Peru, why were these valleys missed?

In order to reduce the archeological history of a region to a few pages of text, elaboration of detail must be neglected and rather categoric statements made. The picture of the north coast given here touches briefly the major periods which are part of the published record to-day. For convenience a résumé of the periods is given in conclusion.

RÉSUMÉ OF PERIODS ON NORTH COAST

Pre-civilization period as yet unknown.

Early Chimu Period:
Well-developed art and artifacts. Subdivisions of this period will probably be isolated, but as yet it must be treated as a unit.

Middle Chimu Period:
A combination of a highland type from the Callejón de Huaylas region and a decadent Early Chimu.

Black, White, Red Period:
Influence from the central coast of Peru moves north creating, at best, a brief period and soon mixing with Middle Chimu to form numerous local styles.

Late Chimu Period:
A north coast development of all Middle Periods plus a revival of Early Chimu influence, with a characteristic smoked blackware pottery.

Inca Period:
The Inca civilization from Cuzco conquers the north coast in the fifteenth century.

Spanish Period:
The Spaniards arrive in the sixteenth century.

PHYSICS AND METAPHYSICS

By Dr. PAUL S. EPSTEIN

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THE word "metaphysics" indicates by its derivation that its subject is beyond physics, beyond the inquiry of scientific method. What possible bearing on questions of metaphysics can then have the progress of modern science? The answer is that there arises, once in a while, a border dispute between these two spheres of human thought, each claiming a province for itself. If science gets the better of the argument, then a larger or smaller portion of that primeval forest which is philosophy is cut down, cleared, divided into fields and turned over to the several branches of science to be tilled. Circumstances of this sort arose during the last few years when the discoveries of physics brought a thorough revision of the "Law of Causality." The general reader has no difficulty in getting at the facts in so far as they concern science. Many articles and books written on the subject sufficiently bring out the significance of the new results for the philosophy of science.

But the layman is also interested in the other side of the question, in the bearing which this revolution of human thought has on metaphysics. He wishes to know to what extent it affects his cherished beliefs and convictions, and, justly or unjustly, he accuses the scientist of refusing to gratify this wish. For instance, we read in the "Experiment in Autobiography" by H. G. Wells: "It is curious to find that to-day professors of physics . . . are still failing to be . . . lucid on such old-world problems as predestination and free will."

Of course, the wording of this remark is unfair to the "professors of physics," as it seems to imply that they are shirking a duty. In reality, however, predestination and free will are problems rather of divinity than of physics. No fair-minded person can blame the physicists for minding their own business and being reluctant to write or talk about theology. But it is true, on the other hand, that even some of the authoritative popular presentations written by scientists of high standing just stop short of the crucial question: "Do the new results of physics have any bearing on the problem of free will, and if so, what is it?" Probably the reason for this omission lies in the fact that these authors, while well versed in the scientific side of the problem, did not sufficiently analyze its theological aspects. At any event, there is an unquestionable demand for such an investigation. Therefore, I have selected as the topic of my article the question put forward by H. G. Wells, and I am prepared to go deeper into theology than is customary in scientific talks. In this sense should be understood the title, "Physics and Metaphysics."

To be sure, it is not the place of a scientist to take sides in a religious controversy. But when it comes to the question, to what extent a specific position of theology is in agreement or in conflict with the accepted theories of science, then the scientist has the right, and even the duty, to speak up.

I shall begin with a brief exposition of the concept of predestination. Predestination is the doctrine that *all happenings in the universe were foreseen by God from eternity and take place, only, through His will.* None of the major religions of mankind remained unaffected by this doctrine. In ancient times, the Greeks had the notion of the "Moira," the unescapable fate to which all men are subject. The Brahminic Hindoos called a similar concept "Karma" and, in a somewhat milder form it was taken over by Buddhism. In the old testament this doctrine is hardly mentioned, but it is set forth with full force in the apocrypha, especially, in the apocalypses of Esdra and of Baruch.

Predestination became a major difficulty of theology when the Christian church fathers, especially St. Augustine of Hippo, combined the principle of predestination with the Hebrew idea of a personal God who is interested in his creatures and is guiding their steps like a kind father, rewarding the worthy and punishing or forgiving sinners. If all the actions of his creatures were foreordained by God, men have no choice in committing them or leaving them undone: They have no freedom of will. There arises the situation which formed the perennial theme of Greek tragedy: Man is but a helpless pawn pushed about by an irrevocable fate and, yet, a cruel Nemesis holds him responsible for actions which were not of his free choice. The Greeks saw in this a great calamity, an eternal curse hanging over mankind, but not an unjustice, because they did not possess the biblical notion of a kind and gracious Deity. But our modern moral sense revolts at the idea that God should have condemned a part of humanity to eternal suffering (as the technical expression is, "*reprobated*" them) and "elected" another part to everlasting bliss. St. Augustine himself argued that, since man is inherently bad and wicked, there is no unjustice in leaving him to his deserts. As Hamlet says: "Use every man after his deserts, and who should escape whipping?" It may be answered, however, that if mankind is wicked, it is so through the will of God by his decree. Rebecca West, in a little book she wrote about St. Augustine, makes a clever remark about this point of his teachings. He was the first born of his parents and the favorite of his mother, Ste. Monica. He never outgrew the psychology of the favorite child, jealous of his brothers and sisters, and he transferred the spirit of the nursery into his ethical system. Provided he belonged to the elected, he was perfectly willing to have the others damned.

In brief, the difficulty lies in the incompatibility of the two attributes of God: His omniscience and omnipotence, on the one hand, and His all-kindness, on the other. If God is all-wise, He must have foreseen everything, and man can have no free will. But, in order to exercise His justice and grace by rewarding, forgiving or punishing, He must deal with creatures who are free and responsible. It is no exaggeration to say that the larger part of Christian theology was devoted to the problem of predestination. In St. Augustine's own life-time, took place his famous controversy with the British theologian, Pelagius, who held the opposite view that man's will is free and only strengthened and encouraged, in its moral purpose, by divine grace. In the scholastic period, St. Thomas Aquinas was a follower of St. Augustine, and Duns Scotus a semi-Pelagianist. Later the Dominicans represented the Augustinian school of thought, and the Jesuits the semi-Pelagian, which seemed to be the more widely accepted. However, in the seventeenth century the decaying Augustinian views were revived by the Jansenists.

Among the Protestants both Luther and Calvin accepted the doctrine of predestination, while the Dutchman Arminius was the main advocate of "Synergism" (as the Pelagian view of freedom of will combined with grace was called by the Protestants). Even to-day the teaching of predestination is a part of the creed of many Christian denominations, but somehow it has lost its power. The clearer minds among the churchmen of our time admit that *the problem of reconciling the fore-knowledge of God with the free will of Man is insoluble, but they maintain that it need not be solved.* We shall see that there is much wisdom in it which is not only the evasive wisdom of the ostrich.

The philosophical equivalent of predestination is *determinism* which was particularly emphasized by Spinoza. In Spinoza's pantheism God and nature were equivalent, the nature being one of the two aspects of the divine substance, the mind, the other. The wisdom of God had therefore to be translated into the lawfulness and consistency of the happenings of the physical world which constitute determinism.

So much about theology and metaphysics. Let us now return to science. We may ask: "Where from did religion derive the doctrine of predestination?" We have just recognized that predestination is equivalent with determinism, and this, in turn, is only one of the formulations of the *principle of causality,* playing such a big rôle both in science and in philosophy. Much has been written about causality, but most of the discussions are concerned with its psychological and metaphysical aspects which are entirely beside our point. We shall be interested here only in the logical aspect related to the fundamental assumption of Aristotelian logic that it is possible to deduce from certain given propositions (premises) another proposition (conclusion) in a unique way. Meaning by this that, when the premises are, in two cases, the same, the conclusion is also the same. Since logic is the instrument for the interpretation of our scientific experience, the principle of causality has been taken over by science. The material of science lies in its facts or observations; they take the place of the premises and conclusions in the scientific applications of logic. As understood in science, the law of causality can, therefore, be stated in these words: a given set of earlier observations (causes) is always followed by a uniquely determined set of later observations (effects). This principle turned out to be in agreement with the scientific facts, *within the limits of observational errors.* Of course, the effects of any set of conditions will be, in their turn, the causes of new phenomena at a still later time, and so on. In this way we arrive at the notion of the causally connected chain of observations and at the deterministic world picture which received its sharpest formulation by Laplace in the following paragraph from his theory of probabilities:

> An intellect to which were known all the forces acting in nature, at a given time, as well as the positions of all things composing the universe, provided it were comprehensive enough to subject all these data to analysis, could embrace in one and the same formula the movements of the largest celestial bodies and of the tiniest atoms. Nothing would be uncertain to it, future and past would be equally open to its eyes.

There is a remarkable similarity between the all-embracing intellect with its world formula, imagined by Laplace, and the omniscient God. Laplace says: "Nothing would be uncertain to it, future and past would be equally open to its eyes." While the psalmist puts it more poetically but less strongly, "A thousand years are in thy sight like yesterday," the basic idea is in both cases the same. We begin to suspect that the religionists created their God in the image of a perfect scientist. Of course, we do not imply that they were influenced either by Aristotle or any other representative of science. What we mean is that the acceptance of the concepts in question was an act of scientific thinking on the part of the founders of religion themselves. They got hold of a principle of science, the law of causality, and incorporated it into their system as an article of faith, the doctrine of predestination. This was a very unwise thing to do: An article of faith must be absolute and beyond human inquiry, while a principle of science is never final but always subject to refinement and revision. Of course, neither the metaphysicians nor the scientists realized that the principle of causality was not an absolute truth.

Both declared it a "necessity of thinking," but it happened time and again in the history of science that what was considered a *necessity of thought* turned out to be only a deeply ingrained *habit of thought*. The experience seemed to indicate that the same causes always produce the same effects and man came to believe that it must be so and never could be otherwise However, when the new discoveries of physics proved to the scientists that this view is mistaken, they abandoned determinism without much trouble. The difficulty with any positive statement in science is that it can not be proven absolutely but only *within the errors of observation*. It is clear that accuracy is very essential for the Laplacean hypothetical intellect. The slightest error in the determination of the direction and velocity of a moving body will lead to a deviation from the calculated position which will increase with time. After the lapse of a sufficiently long time the body will be found very far indeed from where it is expected, be the lack of precision ever so slight. In other words, absolutely accurate data must be available to the intellect or its omniscience will cease after a shorter or longer time and the whole world picture of Laplace will collapse. Is the required absolute accuracy possible?

In Laplace's own time the experimentation was very crude and the observational errors rather large. It was surmised, however, that this state of affairs was wholly due to the limitations of the observer and not to any peculiarities of the laws of nature themselves. The point of view of Laplace implies the belief that in the hands of an ideal experimenter the accuracy could be increased without limit. This is the place where the modern ideas differ from the old ones. It is true that the experimental precision was, and still is, increasing at an ever accelerated rate so that the modern instruments and the modern technique are marvels of accuracy as compared to those which were familiar to Laplace. But at the same rate as the methods of science were refined they were applied to the measurement of smaller and smaller quantities, so that the ratios of the errors to the measured amounts have not greatly decreased. Science has now the proof of the corpuscular structure of the world: the ultimate units of matter are called electrons, protons, neutrons, those of light are known as photons. The observation of such systems, without disturbing them in their natural course, would require means which are delicate in comparison with them. However, such means do not exist: the only way of learning something about the motion of an electron or photon is to observe its action on other electrons and photons. But in this interaction the original state of motion of the particle is changed. This is the inner reason for a very fundamental law of physics discovered a few years ago, the so-called *principle of indetermination*, which states that the position and the velocity of a particle can not be accurately determined at the same time (and which also states the minimum limits of the experimental error).

How does the principle of indetermination affect the law of causality? We may say that it lies beyond causality: the principle of logic remains true that from given premises there always follows a unique conclusion, but it does not apply when there are no premises or not sufficiently accurate premises. Science can no longer invoke causality without reservations: when there is no precise knowledge of the causes, the effect can not be predicted with absolute certainty. It must be distinctly understood that this lack of precise knowledge is inherent in the nature of the laws of the physical universe. It is well to mention here an objection, so natural that it is raised by novices almost regularly: "Granted that the knowledge possessed by the scientist leaves the future motions of a particle partially indeterminate. How can they be sure that this knowledge is complete, that there do not exist other measurable parameters which are still hidden to them, but would be apparent to the more powerful intellect envisioned by Laplace? This additional information could make the problem determinate and causal in the sense of the classical theory." In the early stages of the modern development the question of the "hidden parameters" was amply discussed. Of course, it would be dogmatic to assert that their existence is entirely out of the question. However, it is safe to say that most scientists consider it as very unlikely and that such parameters could not be introduced without abandoning or radically changing the whole mathematical structure of the now existing theory.

After all, for the purpose of the present analysis it is sufficient to have in mind that the causal point of view is not the only possible one. Modern science has developed another (the statistical) standpoint which is just as logical and self-consistent and is in far better agreement with the experimental facts, as they are at present known. If we shift our ground to the new point of vantage the question as to the accurate simultaneous determination of position and velocity simply loses its meaning. The hypothetical intellect of Laplace, be it ever so grandiose, is subject to the same limitations as every other observer and its world formula becomes useless. As it works out, the intrinsic error of observation is comparatively unimportant for large bodies and significant only for small particles. The intellect could, therefore, give a valid prediction of the motion of planets and other celestial bodies for a long period of time, but, in the case of atoms and electrons, its calculations would fail immediately.

The difference between the old (deterministic) and the new point of view, in relation to predicting the future, is best illustrated by a simile. Let us consider, *on one hand,* the surface of the moon: At present, we can not see its minute details. However, we are sure that we could build telescopes sufficiently powerful to discern them. It is only a question of money and technology. Let us take, *on the other hand,* the crude reproduction of a photograph in a newsprint. Here, too, we can not see the details because they are blurred. But unlike those of the moon, no amount of magnification, no lenses or microscopes can ever make them visible. In a similar way, the future is not accurately predictable because the structure of space and time is inherently blurred and fuzzy. Even the most omniscient and omnipotent being can not see things that are not there, so that this is no reflection upon the wisdom and might of God. Our comparison is also adequate in bringing out the fact that the principles of science permit the prediction of the rough general features of future events and, only, deny the possibility of foreseeing their finer details.

It is clear from this description that the new discoveries of physics sound the death knell to the concepts of determinism and predestination. It has often been assumed, tacitly or explicitly, that this remark also disposes of the even more important question of the free will; namely, in favor of its existence. This is, however, an entirely erroneous assumption. The bearing of the changed point of view in science on the freedom of will is an independent problem requiring a separate investigation. *It is our contention that the traditional linkage between determinism and free will is converted into its opposite on the newly shifted ground of science.*

There always have been two schools of thought among the metaphysicians. Those of the first school (the "Vitalists" and "Neo-Vitalists") hold that the laws derived by science for dead nature have only a limited application to the operation of the psyche and to the actions of man. It is obvious that discoveries in the field of physics will not affect their views on the freedom of will which, according to them, belongs to a different sphere. To the other school belong the "Mechanists," who maintain that human behavior is governed by the same laws as physical nature. What conclusion must the Mechanists draw from the principle of indetermination? From the old point of view, the negation of determinism automatically admitted the free will as a possibility. But, as we shall see, this connection of the two principles is no longer true. Freedom of will implies man's ability of choosing and directing events. But the new principles of science do not grant him this ability any more than the old ones. Owing to the inherent inaccuracy of physical description, the same causes may produce, at different times, different events. But these events are unpredictable and subject only to chance. This implies, of course, that neither man nor God can direct these events, because, if he could guide them, he also would be able to foresee them. If under the reign of the principle of causality man was a helpless tool of predestination, modern science makes him, in part, an equally helpless plaything of blind chance. It seems that this simple fact has not been generally recognized. The reason for this was pointed out in our introduction. Scientists, as a class, are not greatly interested in the bearing of their results on philosophy. Even those of them who wrote on the subject for popular consumption devoted most of their attention to the scientific side and touched upon the metaphysical implications only in a desultory manner without clearly realizing that determinism and free will involve, in this connection, two different problems. However, once the distinction is made, the argument becomes quite cogent and conclusive.

We conclude with a brief summary of our main points: (1) The views of modern physical science are incompatible with the doctrines of predestination and determinism which are no longer tenable. This statement should not be construed as an attack upon religion and metaphysics; in fact, it should be a boon to them. It will be well to repeat here that the metaphysicians were those who invaded the field of science by postulating as a truth the religious equivalent of the law of causality. In doing this they quite unnecessarily created for themselves difficulties which they could not resolve. Science is now showing them the way out of the dilemma. (2) The discoveries of physics referred to do not change, in any way, the status of the problem of the free will. Followers of the mechanistic point of view (who believe that the laws of nature and of the human mind operate in the same way) must, therefore, continue to deny freedom of will. Members of the vitalistic school, on the other hand, who claim that human behavior is not subject to the same laws as the physical world, are at liberty to accept the will as free. Their point of view becomes now a little more self-consistent because it does no longer get in conflict with predestination.

I wish, however, to add a word of warning: Although, at present, science can not answer the question whether the laws of the human psyche and of dead matter are the same or not, it will be able to answer it in the course of time. It is definitely a question of science and not of metaphysics. Mechanists and vitalists may hope that the future will vindicate their particular views, but they may not claim for their hopes the dignity of metaphysical postulates.

A TOUR THROUGH PROBABILITY DOMAINS

By E. C. MOLINA

SWITCHING THEORY ENGINEER, BELL TELEPHONE LABORATORIES

ON a tour, whether by train or boat, it is good form to be sociable and join your fellow passengers if they propose a game of bridge.

But playing bridge is more than a pastime. The implications of card shuffling have taxed the mathematical powers of such men as Poincaré, Markoff, Hadamard, Hostinsky, Frechet. They posed and discussed this problem: Given an initial arrangement of the cards, what is the probability that after a specified number of repetitions of a particular way of shuffling them, the cards will be found arranged in a preassigned order?

Poincaré, Markoff, *et al.*, proved that if the number of shufflings or operations on the cards (to use their more technical language) approaches infinity, then the probability asked is independent of the initial arrangement of the cards or of the shuffling method used. They proved several other theorems, all of which are now to be found in the literature under the caption "probabilities in chain."

Let us consider a method of shuffling which would be frowned upon at a bridge tournament, but which is pregnant with meaning for the scientifically minded.

Put half of the cards in a box labeled A, and the other half in a box labeled B. Shake the boxes vigorously and draw a card simultaneously from each box. Next, place in A the card drawn from B and in B the one drawn from A. Call this sequence of drawings and interchange of locus an operation and repeat the operation a large number of times. Bearing in mind that half of the cards are red and the other half black, one will be prepared to consider a whole class of problems in molecular physics. But before taking up the physical problems, permit me to restate the card problem in the form that Laplace gives it in the "Théorie Analytique des Probabilités":

> Consider two urns A and B each containing n balls and suppose that of the total number of balls, $2n$, as many are white as black. Conceive that we draw simultaneously a ball from each of the urns, and that then we place in each urn the ball drawn from the other. Suppose that we repeat this operation any number, r, of times, each time shaking well the urns in order that the balls be thoroughly mixed; and let us find the probability that after r operations the number of white balls in urn A be x.

As in the case of the cards, after a large number of operations, the probability in favor of any specified division of the white and black balls between the two urns is independent of the initial arrangement. Therefore, with a finite number of balls there is a finite probability of reproducing the initial distribution. This fact has great significance, particularly if initially all the white balls were in one of the urns and all the black balls in the other urn.

II

Now, if it please the reader, I submit two exhibits connecting the card shuffling or Laplacian ball problem with modern physics.

EXHIBIT A

Lotka, in his "Elements of Physical Biology," Chapter III, under the heading, "The Statistical Meaning of Irreversibility," says:

> Let the vessel A contain 1 gram of nitrogen gas, and let B contain 1 gram of oxygen gas, the communication between A and B being closed. It is a matter of common knowledge that if the stopcock is now opened, the gas from

> A will flow over into vessel B and *vice versa*, and in a short time an equilibrium is reached in which each vessel contains 0.5 gram of each gas. Now, in point of fact, the molecules of gas behave (approximately) like a number of elastic spheres, their equations of motion contain no dissipative term, but are of type (3) (Chapter II). We should, therefore, expect that after a certain lapse of time, the initial condition should return, and that all the nitrogen should once more be contained in the vessel A, all the oxygen in B.

Lotka continues the discussion of this phenomenon with an appeal to probability theory and makes use of the Laplacian ball problem as an illustration.

The physico-statistical ideas quoted from Lotka were epitomized by Bertrand Russell in a popular article entitled "Heads or Tails" (*Atlantic Monthly*, August, 1930) He wrote:

> If you put a kettle on a nice hot fire, will the water freeze? "Certainly not," says common sense, indignantly "Probably not," says physics, hesitantly. According to physics, if every member of the human race put a kettle on the fire every day for the next million million years (during which, according to Jeans, the world is to remain habitable), it is not unlikely that sooner or later the water in one of these kettles would freeze instead of boil(ing).

Of course, by "physics" Russell means modern physics from the point of view of the kinetic theory of matter, or probability.

Exhibit B

In his paper entitled "Application du Calcul des Probabilités á la Théorie du mouvement Brownien,"[1] Hostinsky introduces his section on linear Brownian movements with a short discussion of the Laplacian ball problem.

For the benefit of those unfamiliar with Brownian movements I quote from A. L. Kimball, "College Physics," 2nd ed., 1917.

> The English botanist Brown in 1827 on observing with the microscope very fine particles held in suspense in a mass of water, discovered they were in constant irregular motion, and the smaller the particle the more lively was the motion observed. It is a spontaneous motion that never ceases, and is believed to be caused by the incessant motion of the molecules of the liquid.
>
> The French physicist Perrin has made a careful study of this phenomenon using an emulsion in water of exceedingly fine grains of mastic. He finds by exact measurements of the distribution of the grains and the amount of their motions that they distribute themselves just as should be expected from the kinetic theory, and even deduces by inference from his measurements the number of molecules in a cubic centimeter of gas under standard conditions, finding 30.5×10^{18}, in good agreement with determinations by other methods

III

To solve his ball problem, Laplace first set up an equivalent finite difference equation and then, as an approximation, reduced it to a partial differential equation. I would invite the reader's attention to this differential equation from two points of view, one physical, the other mathematical: (a) The equation has reappeared in modern physics in connection with the theory of Brownian movements. In this connection I will refer you again to the article by Hostinsky in the *Annales* of the Poincaré Institute. (b) The solution of the equation led Laplace to the development of polynomials and an expansion in these polynomials which, to-day, are called Hermitian and Gram-Charlier, respectively.

But what are Hermite polynomials and Gram-Charlier series, more particularly, the Gram-Charlier A series? An analogy will help us here.

A complex problem in dynamics frequently reduces, as we all know, to a combination of several simple harmonic motions. Moreover, a simple harmonic motion is represented mathematically by a sine or cosine function. Therefore, it is not surprising when the analytical solution of the complex dynamical problem comes out in the form of a sine and cosine series. But consider the domain of, let us say, biology. Here the elements of a complex problem are not sim-

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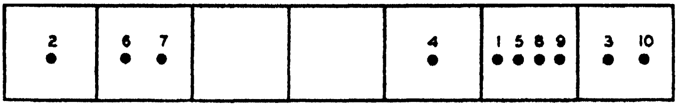
[1] *Annales de l'institut Henri Poincaré*, Vol. III, pp. 47 and 50.



ple harmonic motions; they are simple chance phenomena, simulated by the tossing of pennies or drawing of balls from a bag. In this case, we anticipate that the analytical solution of a complex biological problem would be given by an expansion whose terms represent simple chance events. Such is the character of the Gram-Charlier A expansion, wherein Hermite polynomials of successive orders take the place of the sines and cosines of a Fourier series.

At times even a dynamical problem comes within the scope of Gram-Charlier series. This comes about when the entry of the forces acting or the intensities of their effects are conditioned by circumstances of a random character. As an example one may take the problem of perturbations in the statistical theory of celestial mechanics. Those interested in astronomy could quite well enjoy a pleasant evening discussing Gram-Charlier series with the biologists. As an opener for an exchange of ideas, one might consider the following statement made by Charlier in the chapter dealing with expansions, in the fascicule on astronomy of Borel's "Traite du Calcul des Probabilités et de ses Applicationes":

> Each event, each attribute, each object, each fact, may be regarded as the outcome of the superposition of a very large, or infinite, number of very small influences emanating from sources of perturbations capable of exercising any action whatsoever on the object in question.

IV

Laplace did not stop with two urns. He said:

> We may extend all this analysis to the case of any number whatever of urns; we will limit ourselves here to finding the mean value of the number of white balls each urn contains after r operations.

This more general problem suggests questions regarding the number of so-called *complexions* corresponding to a given statistical state, thermodynamic probability and its relation to entropy.

Consider the above diagram from Page's "Introduction to Theoretical Physics."

The seven squares or cells (boxes) represent elements of extension-in-phase. The ten dots with their identification numbers represent, collectively, one of the many complexions corresponding to the particular statistical state of 1 particle in cell No. 1, 2 in cell No. 2, 1 in cell No. 5, 4 in cell No. 6 and 2 in cell No. 7. For this particular state the total number of complexions is

$$\binom{10}{1}\binom{9}{2}\binom{7}{1}\binom{6}{4}\binom{2}{2} = 10!\,/\,(1!\ 2!\ 0!\ 0!\ 4!\ 2!)$$

The most probable state is the one to which the greatest number of complexions correspond.

Now, with due apologies for being so abrupt and for a purpose which will soon be apparent, I will jump, for a more general statement of the complexion problem, to page 283 of an "Introduction to Statistical Mechanics for Students of Physics and Physical Chemistry," by James Rice:

> Suppose we have present a set of Planck vibrators which each contain a multiple of a unit of energy e. Let there be n vibrators and an amount of energy E available where E/e is an integer. Let us consider a complexion in which there are n_0 vibrators with no energy, n_1 with e, n_2 with $2e$, etc. There are as usual
>
> $$n!\,/\,(n_0!\ n_1!\ n_2!\ \ldots)$$
>
> complexions in a corresponding statistical state, and we have to satisfy the conditions
>
> $$\begin{aligned} n_0 + n_1 + n_2 + n_3 + \ldots &= n \\ n_1 + 2n_2 + 3n_3 + \ldots &= E/e \end{aligned} \qquad \text{(IV. 1)}$$

> Let C be the total number of complexions compatible with these conditions. C will be given by
>
> $$C = \Sigma\, n! \,/\, (n_0!\ n_1!\ n_2!\ \ldots)$$
>
> where the summation is over all possible values of the n *which satisfy.* (IV. 1).

It is not my intention to follow up this complexion problem. My main purpose in introducing it is that Rice evaluates C by the method of generating functions, a method which appeals to me like apple pie to a small boy.

The concept of a generating function suggests itself immediately to one familiar with the history of art.

When the Greeks wanted a Parthenon, they called upon a Pheidias. When the Medici wanted a magnificent tomb in San Lorenzo, they called upon a Michelangelo. But, during the dark ages, when a Pope wanted a beautifully carved portal, for example, there was no Pheidias or Michelangelo to call for. So, instead, scouts were sent out to buy up some ancient building containing a portal of the desired design. Then, the building having been acquired, a wrecking crew was sent to extract the portal.

This method of accomplishing results has turned out to be very fruitful in the mathematical theory of probability, and elsewhere. When a mathematician can not carve a desired function, $f(x)$, he looks around for a generating function, $F(x)$, containing $f(x)$. Then, if necessary, applying some ingenious wrecking tools devised especially for the purpose, he extracts $f(x)$ from $F(x)$.

In the generating function or frequency array (see "Frequency Arrays," Soper, Cambridge University Press, 1922)

$$F(A, B, C, \ldots) = \Sigma\,\Sigma\,\Sigma \ldots (p_{a,\,b,\,c} \ldots)\, A^a B^b C^c \ldots$$

the coefficient $(p_{a,\,b,\,c,} \ldots)$ is for a certain population, the proportion or frequency of individuals each owning, say, a automobiles, b books, c cows, etc. Likewise, with reference to continuous variates, in the generating function, or frequency array,

$$F(A, B, C, \ldots) = \int\!\!\int\!\!\int \ldots f(a, b, c, \ldots)\, A^a B^b C^c \ldots da\, db\, dc \ldots,$$

$f(a, b, c, \ldots)$ gives the proportion or frequency of individuals of, say, age a, blood pressure b, chest expansion c, etc.

The capital letters symbolize characters or attributes in which we are interested, and the frequency array pictures the entire population as divided into categories in accordance with the extent to which an individual possesses each of the characters or attributes.

The method of generating functions constitutes a highway with branches running in all directions. Traveling along it carries one through the entire domain of error theory. The branch built by Soper terminates in a whole family of random flight problems. In Soper's treatment of these problems will be found not only evidence of the power of generating functions, but also a masterly exhibition of how powerful tools should be handled. It will be recalled that random flight problems are of the type: If one, with the aid of an aeroplane, makes a flight of n successive steps, each step of length r in a random direction with reference to the preceding step, what is the probability that at the end of an assigned time interval one is at an assigned distance from his starting point?

The number of physical problems which may be classed together under the heading of random are legion. For example, many, if not most, of those concerned with Brownian movements; the problem of "fading" in radio transmission; the problem which in Volume I of his "Theory of Sound," Lord Rayleigh states as follows:

> We have seen that the resultant of two isoperiodic vibrations of equal amplitude is wholly

> **dependent upon their phase relation, and it is of interest to inquire what we are to expect from the composition of a large number (n) of equal vibrations of amplitude unity, of the same period, and of phases accidentally determined.**

Rayleigh and Karl Pearson may be mentioned as among the pioneers in the treatment of random flight problems.

VI

So far I have submitted for consideration strictly scientific implications of card shuffling. I now invite attention to a shuffling problem which involves, as we shall see, a very delicate ethical question.

In the game of poker each player is dealt five cards. That five-card hand which consists of the ace, king, queen, jack and ten of a suit possesses the highest playing value; it is called a "royal flush." If the cards are dealt at random, the probability that the dealer's hand will constitute a royal flush is only 1 in 649,739 or, approximately, 1 in 650,000. On the other hand, by cheating, the dealer can raise this extremely small probability up to, let us say, 1 in 100.

Now suppose a stranger, who proposed a poker game, dealt the cards and that, when the hands had been played, it developed that he had dealt himself a royal flush: What is the probability that he cheated?

Shall we say that the odds are 650,000 to 100 against his integrity? Such an inference is legitimate only if, before the hands were played, we were in a fifty-fifty state of mind regarding the stranger's ethical status. Certainly no one would bet 650,000 to 100 against him if the occurrence under consideration had taken place within the sacred precincts of a London club, for example. But we are on a train or ship, and signs, hung in conspicuous places, give warning as to the likelihood of our encountering card sharps. Therefore the odds against the good faith of the stranger, who has dealt himself a royal flush, are even greater than those already cited.

The moral to be drawn from the ethical problem we have just discussed is as follows: When an event has happened as the result of the coming into play of one or the other of two causes, A and B, the probability in favor of cause A, for example, as being the cause which actually resulted in the observed event, is proportional to two distinctly different factors; one factor gives the probability in favor of said cause A before the observed event occurred; the second factor is proportional to the probability that, if cause A is in action, then the observed event would occur. The first factor is called the *a priori* existence probability in favor of the cause. Two corresponding factors pertain to the other cause B. The generalization of our little sermon to the case where more than two causes must be considered involves no difficulty other than the use of a greater number of words.

CHANGEABLE COLORATION

ITS MECHANISM AND BIOLOGICAL VALUE WITH SPECIAL REFERENCE TO FISHES

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THE ability to undergo rapid changes of color and shade in response to external stimuli is confined to a very few groups of animals, though these groups belong to several different major divisions of the animal kingdom. Since the mechanisms involved in these changes present essential differences in some of the groups which possess them, we may be reasonably sure that this capacity has appeared several times in the course of animal evolution. The chief groups which display it are the cephalopod molluscs, crustacea, fishes, amphibia and reptiles.

The effector elements which are immediately responsible for these color changes are cells known as chromatophores. These may operate singly or in clusters of a few cells. Speaking particularly of the fishes, we may say that the chromatophores are much branched cells of relatively great size. In form, they may well be compared to a basket star-fish, having a small central disk and radiating branches which subdivide repeatedly. There are various kinds of these chromatophores, but the most important differences relate to the kind of pigment which they carry. Thus we have the most numerous class, the melanophores, which contain the black pigment melanin; the xanthophores and eythrophores—yellow and red, respectively—which contain pigments of the carotenoid type; and the white guanophores or iridocytes which contain crystals of guanin.

In all these the response to a stimulus consists in the shifting of the pigment within the cell. The older view that the chromatophores themselves expand and contract in ameboid fashion has been virtually abandoned, though this misleading terminology unfortunately persists. The darkening of a fish results from the centrifugal movement of the melanin granules, which thus come to fill the branches of each cell and greatly increase the total black area of the skin. In paling, the pigment granules move in a centripetal direction, concentrating in a small mass in the center of each cell. Thus, the same fish, under appropriate stimuli, may change in shade from dead black to pale brown and back again within a few minutes' time. Similar processes occur in the other types of chromatophores.

In fishes, there seems to be an immediate connection between the chromatophores and the terminations of peripheral nerves belonging to the autonomic system. This fact has been substantiated both by histological and by physiological studies.

That the xanthophores are controlled by different nerves from the melanophores is evident from the fact that these two types of chromatophore react independently of one another and often in opposite directions. A fish may become pale and colorless or pale and yellow; dark and colorless (*i.e.*, black or gray) or dark and yellow (*i.e.*, brown). The behavior of the other types of chromatophores is less well known. Recent studies seem to indicate that the centrifugal and centripetal movements of pigment, *i.e.*, dispersion and aggregation, are also controlled by different nerve fibers.

The direct nervous control of chromatophores has likewise been demonstrated for reptiles, though in this group there seems to be a supplementary control through the secretion of the adrenal medulla. In the amphibia, on the other hand, no such direct nervous control appears to exist. Quite the contrary, it now seems probable that the reactions of the chromatophores in the latter group are mediated entirely through endocrine secretions from the hypophysis, carried in the blood. These animals nevertheless react to optic stimuli, as fishes do, though they are more largely influenced than the latter by various other stimuli.

The recent work of Parker and his students seems to show, moreover, that even in the fishes there is a hormonal (or "humeral") control of the chromatophores, supplementary to the nervous control. If the nerve supply of a small area of the integument is severed without disturbing the blood supply, and the fish is then placed upon a white background, the entire body soon becomes pale, with the exception of the denervated area. If, however, the animal remains for a considerable number of hours upon the white background, the denervated area likewise gradually becomes pale. This, along with certain other experiments, would seem to show that some substance diffusing from one cell to another may bring about the same effect upon the chromatophores as stimulation through the nerves. Indeed, it is quite possible that the immediate action of the pigmento-motor nerves themselves is to stimulate the formation of substances capable of causing the concentration or dispersion of the pigment in the chromatophores.

The chromatophores are known to respond in a definite way to various drugs. Dilute solutions of sodium chloride, for example, bring about the so-called "expanded" condition of the melanophores, or more correctly the dispersion of the melanin granules within these cells, while potassium chloride produces the reverse effect. Here, it would seem to be the sodium and potassium ions which are effective. Many anesthetics, ether and urethane, for example, call forth the dispersion of the pigment, while adrenalin causes an extreme condition of concentration. It seems probable that the hormone of the adrenal medulla may normally play a rôle in the color changes of some reptiles.

Whatever the physico-chemical mechanism, the phenomena of pigment migration, as seen in the chromatophores of the scales of a fish, is a fascinating object of study, and could readily be utilized for classroom demonstration. I do not know to what extent this has been done.

As already stated, control of the chromatophores in all animals is effected either directly or indirectly through the nervous system. Color changes may occur in response to a variety of stimuli, photic, thermal, chemical or mechanical. In fishes, optic stimuli are responsible for the most conspicuous and biologically important changes. Here we must distinguish changes of color, in the narrower sense, from changes in shade, the latter denoting changes in the direction of greater pallor or darkness, without any necessary alteration of color proper. A fish placed upon a gray background, for example, assumes a quite different appearance from the one placed upon a brown or yellow background, which is equally pale or dark. Any one who has conducted experiments of this sort with any care knows that the wave-lengths of the light reflected from the background constitute an important element in the situation. While this conclusion has been challenged by some writers on more or less theoretical grounds, it has been sustained repeatedly by carefully planned experiments. That fishes have a real though perhaps restricted color vision can no longer be reasonably doubted.

Many of these chromatic changes of

fishes are remarkably complex, consisting not only of independent responses by the different classes of chromatophores, but of independent changes in different areas of the integument. Thus, in flat-fishes, certain areas may become very pale, others at the same time very dark, giving to the animal a mottled appearance. Moreover, the relative extent of the light and dark areas, in such cases, is closely dependent upon their relative extent in the background at the time. Once more, the resulting mottling is likely to be coarse or fine, depending upon the texture of the background.

I have spoken here of the background. Those unfamiliar with the color changes of fishes sometimes assume that the effective agent in determining the shade assumed by the animals is the total quantity of light to which they are exposed. Thus, fishes might be supposed to become black on a black background, by reason of the low degree of illumination, and pale upon a white background for the opposite reason. That this is far from being a true account of the situation we might suspect from the fact that, when kept in complete darkness, fishes become pale rather than dark. What the fish responds to, for the most part, is neither the total illumination from all sources nor the intensity of the incident light. The effective stimulus is the light reflected from surfaces beneath and around the animal. And even here it is not the absolute intensity of this reflected light which counts. It is rather the albedo of the reflecting surfaces. By albedo we mean the actual light-reflecting capacity of an object or substance, without reference to the degree to which it is illuminated. Thus, a gray object has a lower albedo than a white one, even though the former may be so placed as to reflect vastly more light than the latter. Simple photometric measurements suffice to show that even a dull black surface, placed in direct sunlight, may reflect more light (more *white* light, to be precise) than a white surface in the diffuse daylight of a laboratory room. And yet a fish becomes black, or nearly so, upon the former and very pale upon the latter.

The fish's response to a given albedo is to a large extent independent of absolute illumination. Here we have a striking parallel between the physiological responses of a fish and certain well-known facts of light perception in ourselves. I refer to the apparent constancy of a given color or shade under widely different conditions of illumination. It is the problem of "color-constancy," so-called, which has received considerable attention from experimental psychologists. Our perception of any one object in the visual field is not an isolated fact. It is influenced more or less by the entire visual field. In the same way, the fish reacts not merely to the light rays reaching its eyes from the background, but reacts, in some way, to the ratio between these rays and the incident light. Neither in man nor the fish is the making of the necessary "correction" for general illumination an act of judgment. It occurs entirely on the perceptual plane.

What, then, is this distinction between incident light and background? In the fish it seems probable that the animal's reaction is determined by the relations which obtain between the upper and lower portions of the visual field. For example, I long ago determined that a flounder made not the least response to a plate bearing a strongly contrasting pattern when this was suspended close over it. When, however, the position of the plate was reversed, so that the fish came to lie upon this same pattern, an appropriate rearrangement of its color markings occurred.

More recently, I have experimented with transparent celluloid caps or "false corneas," fitted over the eyes of the fish *Fundulus parvipinnis*. When the lower half of this "cornea" was painted black, thus obscuring the corresponding half of the visual field, the fish invariably became dark, usually as black as when placed upon a black background. On the other hand, when the upper half of the visual field was obscured in this way, the fish did not become darker in consequence, but usually became paler than it would otherwise be upon a given background, unless, indeed, the background happened to be white. Apparently, darkening of the upper half of the visual field worked in the same direction as making the lower half paler.

Such experiments strongly suggest a dorso-ventral polarization of the retina, such that a given light stimulus will call forth a different response, depending upon the half of the retina which is stimulated. Or, possibly, this polarization occurs in the central nervous system. It is hardly necessary to add that such experiments rule out absolutely any interpretation of these adaptive color changes as direct and simple responses to photic stimuli, without regard to the complex anatomical and physiological mechanisms involved.

In the foregoing discussion, I have had in mind chiefly those rather prompt changes of color or of shade which result from the shifting of pigment within the chromatophores. I think that most of us formerly believed that the color-changes of fishes were altogether of this type. It was for long not realized that continued subjection to appropriate stimuli might result in large changes in the amount of pigment actually present in the tissues. Experiments of recent years have shown that in some fishes, at least, the black pigment melanin may be increased manyfold by a sojourn of a few weeks upon black, while it may be to a large extent eliminated by a sojourn on white. A more nearly quantitative series of experiments has recently been conducted by Mr. Peter Doudoroff and the writer, in which we sought to measure with approximate exactness both the conditions of illumination and the amount of melanin produced or lost.[1] These experiments, which were performed upon gobies, have revealed no such extreme differences in pigmentation as were encountered in some previous experiments with other fishes. They have shown, none the less, (1) that the amount of melanin produced (or retained) is strongly influenced by the albedo of the background, and (2) that it is influenced, though to a much smaller extent, by the absolute intensity of the illumination. While we do not wish to generalize at the present stage of this work, it may be allowable to point out that in our more brightly lighted cabinet, at least, the melanin content of the fishes tended to vary inversely as the logarithm of the albedo of the background. The relation of such a result to the "Weber-Fechner Law" is obvious.

As regards the yellow pigment, xanthophyll, the amount of this has been determined by Dr. D. L. Fox and myself for several species of fish.[2] The stock of xanthophyll in a fish seems to be derived entirely from its food and thus, ultimately, from the plant life of its habitat. Hence it must be maintained by appropriate feeding. In some fishes, at least, it is rather rapidly lost if lacking in the diet. It is interesting to note that this loss, in one species which we have studied, is considerably more rapid in specimens kept in white aquaria than in ones kept in black, gray or yellow aquaria. It was unexpected, however, that the amount of xanthophyll should fail to be closely correlated with the visible coloration of the fish. The distinctly yellow fishes from yellow aquaria yielded, to be sure, more xanthophyll than the nearly colorless specimens from white aquaria.[3] On the other hand, the greatest quantity of all was obtained from the almost totally black fishes from black aquaria. Here, plainly, the xanthophyll was masked by the melanin

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[1] The report of these studies is in press.

[2] *Jour. Exper. Zool.*, 66: 263–301, 1933; *ibid.*, 71: 101–123, 1935; *Proc. Nat. Acad. Sci.*, 21: 330–340, 1935.

[3] That is, they did so with one interesting exception. Fishes which had been kept for a considerable period upon white, followed by a briefer sojourn upon yellow, were more highly colored than ones which had been kept for a considerable period upon yellow, followed by a briefer sojourn upon white. Nevertheless, the former yielded less xanthophyll than the latter.

In conclusion, we must face the question: What is the use of this remarkable mechanism for color change? The biochemist has to do only with the origin and composition of the pigments here concerned. The physiologist is interested primarily in the working of the mechanism. But the naturalist wishes also to know what rôle this plays in the life of the organism. That it plays some important rôle can hardly be doubted. Some substances which occur in the animal body may be dismissed as mere by-products of metabolism, and some structures may reasonably be regarded as functionless, at least at the present moment of evolution. But a complicated mechanism, consisting of many interrelated parts, can hardly be treated in any such summary fashion, particularly when it has been evolved independently in several different major divisions of the animal kingdom. And the fact that these changes of color are predominantly in the direction of rendering the animals inconspicuous can be ignored only by those who are not disposed to face the facts.

Unfortunately, there appear to be a number of such persons in existence and these have been vociferous in their assertions. Several biologists in different parts of the world have intermittently cudgeled the entire "protective coloration" hypothesis as being "anthropomorphic," "teleological" and unworthy of serious consideration by scientific men. It is not my intention here to enter into this controversy in any general way. Indeed, I am ready to admit that a certain fraction of the criticism is valid. I will merely refer, in conclusion, to some rather recent experiments of my own which show beyond cavil that the capacity of a fish to adjust its color scheme to its background may be of decisive value in determining the animal's survival.[4]

The experiments in question were conducted with a small species of fish (*Gambusia affinis*) as prey, and certain fish-eating birds and carnivorous fishes as predators. The fishes used as prey were first "conditioned" by being kept in black or white tanks for considerable periods, until their dark or pale liveries were fixed to the extent that individuals of different history could still be distinguished from one another after some hours' sojourn upon a common background. Throughout a considerable and varied series of experiments, the predators uniformly devoured a much larger proportion of the more conspicuous type of fish offered to them, even though both types were plainly visible, at least to the human eye.

To many, the inevitability of such results as these may seem quite obvious, and to such, indeed, the experiments themselves may appear altogether superfluous. But they could hardly be so regarded by those who continue to deny the effectiveness of all "so-called protective adaptations."

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[4] *Proc. Nat. Acad. Sci.*, 20: 559–564, 1934; *ibid.*, 21: 345–353, 1935; *Amer. Nat.*, 69: 245–265, 1935.

THE CREATIVE YEARS: "BEST BOOKS'

By Dr. HARVEY C. LEHMAN
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WHAT are the creative years? What are the chronological ages at which men (and women) are most likely to write literary masterpieces? Certain modern students of this subject have tended to overestimate the literary productivity of early youth; others have insisted upon the literary fecundity of old age and have perhaps exaggerated it Overstatement is most likely to occur when an investigator merely lists a limited number of writers who have done excellent writing at some particular age level.[1] The technique of citing outstanding books that have been written by men of any given chronological age (and omitting the perhaps more frequent achievement at other age levels) is likely to yield an erroneous impression. The question is not whether there have been men of a given age (or age interval) who have produced excellent writing, but whether, in proportion to their numbers, men of some chronological age levels have produced more or less than men of other age levels.

The investigation that is reported herein reveals that superior books have been published by authors of almost every age level beyond early youth. Does it necessarily follow that there are no significant age differences with reference to literary creativity? Must it be inferred that there is a long period of maturity during which the publication of literary masterpieces is as likely to occur at one age level as at another? The present study provides tentative answers to the foregoing questions.

METHOD

In two previous articles[2,3] the fact has been stressed that when age differences in creativity are to be studied, it is necessary to take account of the varying numbers of individuals that are alive at successive age levels. For if more men are alive at the younger than at the older age levels, the younger age groups might publish more outstanding books merely because of their greater numerical strength Accurate conclusions regarding the chronological ages at which individuals have most frequently produced literary masterpieces involve therefore: (1) Assembling a reasonably large sampling of very superior books, and (2) Determining the average number of these books that were published by each age group

Several additional facts must be considered. It obviously is not possible to study the entire life work of authors who are still living and writing. There is no way of knowing what the living writers will accomplish during their later years. Moreover, books that are hailed with acclaim by one's contemporaries may not be regarded as great books by a critical posterity. The present study includes for the most part, therefore, data for deceased writers.[4] For these the record is complete, and future research will probably change it only slightly, if at all.

Which books should be included in a list of "best books"? How can we render a valid decision with reference to this question? Probably most readers would agree that no one individual is able to make a trustworthy decision as to which are the world's best books. At this point the writer wishes to express his indebtedness to an unintentional collaborator. In 1924, Mr. Asa Don Dickinson, librarian of the University of Pennsylvania, made a composite study of more than 50 "best book" lists. Dickinson made his study because he believed that his compilation would eliminate questionable titles. To quote from his own statement:

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[1] *Cf.*, in this connection, W. A. N. Dorland. *The Welfare Magazine*, Vol. 18, Part 3, pp. 1307–1329; 1444–1466, 1927.

[2] Harvey C. Lehman, THE SCIENTIFIC MONTHLY, 43: 151–162, 1936.

[3] Joseph B. Heidler and Harvey C. Lehman, *The English Journal* (College Edition), 26: 294–304, 1937.

[4] There will be some exceptions to this rule. These exceptions will be noted when they occur.

> No single authority is an absolutely safe guide. . . By a careful collation of a large number of authoritative lists we can sift out the questionable titles, and be sure that no indispensable ones have been overlooked. It is by this laborious process that the One Thousand Best Books described in the following pages have been chosen.[5]

For studying the chronological ages at which best books have been most frequently published, a decided advantage is obtained by utilizing a composite list such as that of Dickinson When they were making their original selections, the various compilers whose work was investigated by Dickinson were apparently not thinking of age differences in creativity. It is therefore probable that, collectively, the compilers exhibited no bias for or against any particular age group. This point is an important one for, when studying the relative creativity of persons of different chronological age levels, the investigator should divest himself of all bias This impartial attitude is most likely to be maintained when the compiler is thinking not of age differences but solely of literary merit.

LITERARY MASTERPIECES

Fig. 1 presents the chronological ages at which 224 significant books were first published by 101 noted authors. Each of the 224 titles employed in the construction of Fig. 1 appears on 8 or more of the best book lists studied by Dickinson. These 224 books are obviously works of very superior merit. Because each of the 224 books appears on 8 or more of the best book lists, they will be referred to hereinafter as "Grade 8" books. Similarly, the expression "Grade 12," as used in this discussion, applies to books which appear on 12 or more of the best book lists studied by Dickinson. The foregoing system of notation will make for brevity of expression.

In studying Fig 1 it should be borne in mind that this figure presents the *average* number of Grade 8 books per chronological age level. Adequate allowance is thus made for the relatively large number of authors alive at the younger age levels. For example, in obtaining the data set forth in Fig. 1, it was found that at the age interval 40 to 44 inclusive, the average number of Grade 8 books per author was .1004, whereas, at the age interval 65 to 69 inclusive, the average number of Grade 8 books had fallen to .0125. In Fig. 1 the curve is so drawn as to be only about one eighth as high at ages 65 to 69 as at ages 40 to 44, thereby indicating that average productivity was only about one

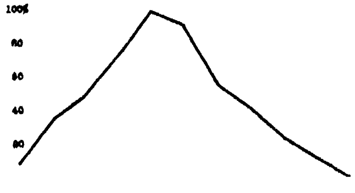

FIG. 1. AVERAGE NUMBER OF BEST BOOKS BY AUTHORS DURING EACH FIVE-YEAR INTERVAL OF THEIR LIVES. THIS GRAPH IS BASED ON FIRST PUBLICATION OF 224 SIGNIFICANT BOOKS WHICH WERE WRITTEN BY 101 NOTED WRITERS.

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[5] Asa Don Dickinson, "One Thousand Best Books," p. xii. Garden City: Doubleday, Page and Company, 1925. Pp. xvii + 416.

eighth as great at ages 65 to 69 as at ages 40 to 44.[6]

If, regardless of the number of authors that remained alive, the older writers had published books of Grade 8 quality at the same average rate as did the writers of ages 40 to 44 inclusive, the curve in Fig. 1 would remain as high at the older age levels as it is at the age interval 40 to 44 inclusive. Actually, the curve in Fig. 1 descends markedly after attaining its peak at the age interval 40 to 44.

Why does this marked descent in the curve of Fig. 1 occur? Is this decrement due to the phenomenon of old age? It is commonly supposed that the technique of producing literary masterpieces is one that is acquired slowly and painfully. One might logically have anticipated, therefore, that, having acquired this desirable and rather rare technique, the capable author would continue to employ it over a period of many years. This, of course, does occur in the case of some few authors. It does not occur, however, in the majority of instances.

In Fig. 1 a small polygon may be seen at the extreme right of the curve. This phenomenon is due solely to the fact that the second part of Goethe's "Faust" was published when Goethe was more than 80 years of age. Since, of the 101 authors whose works were employed in the construction of Fig. 1, only a very few were alive at age 80, Goethe's single publication at this advanced age interval yielded an average of .015 for writers of ages 80 to 84, inclusive. Study of the statistical distribution that is pictured in Fig. 1 reveals, however, that the publication of a work of such great merit by a writer who is more than 80 years of age is most unusual. Indeed, appropriate computation suggests that, if an author is destined to produce a book of such unusual merit as to be chosen by 8 or more compilers of best book lists, the chances are much less than one to a thousand that the author will first publish the book when he is beyond 80 years of age.[7]

Fig. 2 reveals the age intervals during which superior books of varying orders of merit were first published. In Fig. 2 the following characteristics are perhaps worthy of notice. (1) All four curves reach their peaks during the forties and three of the four curves attain their peaks prior to age 45. (2) The four curves all exhibit rapid descent prior to age 50, and (3) at ages 55 to 70 there seems to be a tendency for the curves

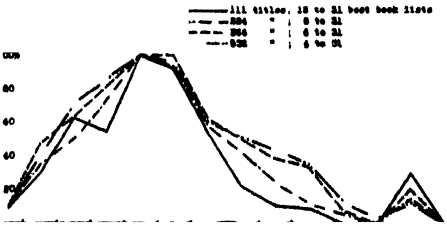

FIG. 2. AVERAGE NUMBER OF BEST BOOKS BY AUTHORS DURING EACH FIVE-YEAR INTERVAL OF THEIR LIVES.

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[6] In constructing the graphs that accompany this article, the data were reduced to a percentage basis by the following procedure. The peak of each statistical distribution was arbitrarily assigned a value of 100 per cent., and the other averages within the same statistical distribution were assigned proportionate percentage values. For example, in Fig. 1, the peak of the distribution occurred at ages 40 to 44, inclusive. At this latter age interval the average number of books per author was .1004. In Fig. 1 the decimal .1004 is plotted therefore as 100 per cent. At the age interval 65 to 69, inclusive, the average number of books per author was .0125. This latter decimal fraction is equivalent to 12 per cent. of the maximum production (12 per cent. of .1004) and in Fig. 1 the decimal .0125 is therefore plotted as 12 per cent. The foregoing procedure offers several advantages and it presents no serious disadvantages if the method of plotting is borne in mind when interpreting the graphs.

[7] At the time of publishing the second part of "Faust" Goethe was 81 years of age. This chronological age is 3.56 standard deviations above the mean of the statistical distribution that is pictured in Fig. 1.

that picture the very best work to descend most rapidly with advance in age. Thus, from ages 55 to 70 the curve for books which were placed on 12 or more best book lists falls off more rapidly than does the curve for books which were placed on only 8 or more lists. And the curve for books which received 8 or more endorsements falls off slightly more rapidly than does the curve for books which received only 6 or more endorsements. This tendency for very superior publication to cease at slightly younger chronological age levels than does publication of somewhat lesser merit will receive later comment

AN AUTHOR'S ONE BEST BOOK

Fig 3 sets forth the chronological ages at which certain noted authors first published their one best book In obtaining data for the construction of this figure it was assumed that the one title by a particular author which appeared most frequently on the best book lists was that author's best book. Several other rules were adhered to in making the selections. For example, authors who published no book which received as many as 4 endorsements were omitted. Other writers were omitted when two or more of the books on their lists were tied for first place. In such instances it was not possible to select the author's *one* best book.

By means of the procedure that is described in the preceding paragraph the following data were obtained for Fig. 3: (1) The chronological ages at which 80 authors first published what is probably their one best book, each of the 80 titles having been endorsed 8 or more times, and (2) the ages at which 241 authors first published their one best book, each of the 241 books having received 4 or more endorsements In Fig. 3 both curves attain their peaks at the age interval 35 to 39, inclusive. And the curve for the better books (those of Grade 8) rises more slowly and falls off more rapidly than does the curve for books of Grade 4[8] This phenomenon again suggests that the very best books tend to be published during a somewhat narrower span of life than do the aggregate thereof.

LONG-TERM BEST SELLERS

Best sellers are not necessarily best books. Nevertheless, best sellers that maintain their popularity over a long period of time are books that make a strong appeal to humanity in general. Therefore, it will probably be granted that, even though best sellers are not

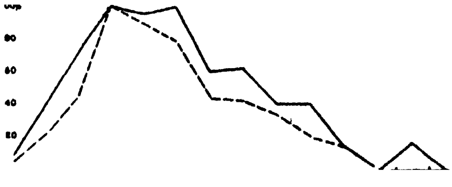

FIG. 3. CHRONOLOGICAL AGES AT WHICH 241 NOTED AUTHORS FIRST PUBLISHED THEIR ONE BEST BOOK, AND CHRONOLOGICAL AGES AT WHICH 80 MORE HIGHLY NOTED AUTHORS FIRST PUBLISHED THEIR ONE BEST BOOK.

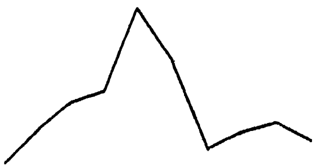

FIG. 4. AVERAGE NUMBER OF BEST SELLERS BY AUTHORS DURING EACH FIVE-YEAR INTERVAL OF THEIR LIVES. THIS GRAPH PRESENTS DATA FOR 47 AUTHORS, WHO WROTE 60 BOOKS, EACH OF WHICH HAVE HAD SALES OF MORE THAN 500,000 SINCE 1875.

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[8] "Grade 8" books are those which appear on 8 or more of the best book lists studied by Dickinson; "Grade 4" books are those which appear on 4 or more of the best book lists.

necessarily best books, long-term best sellers are worthy of study. What are the chronological ages at which authors have most often produced long-term best sellers?

In *The Publishers Weekly* for April 21, 1934, Mr. E. A. Weeks[9] lists 65 books, each of which have had sales of more than 500,000 copies since 1875. Some of the books that are included in the Weeks list have achieved scores of editions; some of them have been printed and sold by the million Fig 4 sets forth the ages at which 47 different authors first published 60 of the 65 best sellers that are listed by Weeks[10] In proportion to their numbers, authors publish long-term best sellers most frequently when they are not more than 40 to 44 years of age[11] Note the phenomenal descent of this curve from ages 42 to 52! To what is this very marked descent to be attributed?

Best Books by Women

Lists of best books by women writers have not often appeared. In 1933, however, a committee acting for the National Council of Women of the United States published a list of best books by American women.[12] What were the chronological ages at which these American women first published[13] their best books? Fig 5 presents the data. Because of the small number of women authors that would otherwise have been available, it was necessary in the construction of Fig. 5 to include data for a number of living writers. In Fig 5 the peak of the curve occurs at ages 35 to 39, inclusive.

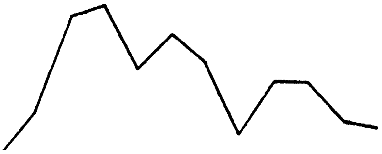

Fig. 5. Average number of best books by American women during each five-year interval of their lives. This graph is based upon date of first publication of the 100 best books by American women during the past 100 years 1833–1933. (Many of the authors are still living.)

Appraisal of the Works of Contemporary Writers

The Committee on College Teaching of the National Council of Teachers of English recently prepared a list of best books.[14] Some of the authors of these latter books are still living; many of them are long since deceased Data were available for 337 books by 203 deceased authors and for 396 books by 285 living authors. The average number of books per author was practically the same for the two groups, namely, 1.39 and 1.66. Fig. 6 reveals that, as compared with the age-curve for the deceased, the curve for the living writers tends to ascend somewhat more slowly and it tends also to sustain itself longer at the older age levels.

Fig. 6 conveys the suggestion that

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[9] Edward A. Weeks, *The Publishers Weekly*, 125: 1503–1507, 1934.

[10] For the five other books that were listed by Weeks, dates of first publication were not available.

[11] Data for a few living authors were employed in the construction of Fig. 4. In this instance the utilization of such data was thought to be allowable, since the large sale of the books is already an accomplished fact.

[12] Anita Browne (*Chairman*), "The One Hundred Best Books by American Women During the Past Hundred Years· 1833–1933." Chicago: Published by Associated Authors Service. 1933. Pp. 128.

[13] In this manuscript the words "first published" refer not to a given author's first publication but to the year during which a given book first appeared in print.

[14] Atwood H. Townsend (*Chairman*), "Good Reading." Prepared and published by the committee on College Reading, for the National Council of Teachers of English. New York: Copyright by the Committee 1935. Pp. 79.

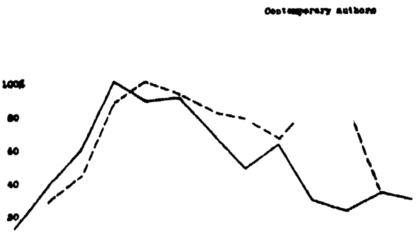

FIG. 6. AVERAGE NUMBER OF BOOKS "WORTH KNOWING" WHICH WERE PUBLISHED DURING EACH FIVE-YEAR INTERVAL (1) BY LIVING AUTHORS, AND (2) BY DECEASED AUTHORS.

superior books that are written by young living authors (who are likely to be unknown) tend to be rather slowly recognized. On the other hand, the writings of older living authors (who more frequently have established their reputations) tend to be overrated. If we accept the judgment of posterity as the more valid criterion, it seems probable that a halo effect influences appraisal of the works of older living authors more frequently than it influences evaluation of the works of deceased writers. Possibly this phenomenon helps to explain why investigators have often failed to discern the very marked age differences that exist with reference to the writing of best books.

SELECTIVE BIBLIOGRAPHIES

In preparing lists of allegedly superior literary works, some compilers list practically everything that a given author has published. Other compilers carefully avoid completeness and pride themselves on the fact that their bibliography is really selective. What is found when data are procured from bibliographies that vary widely in the degree to which they are selective?

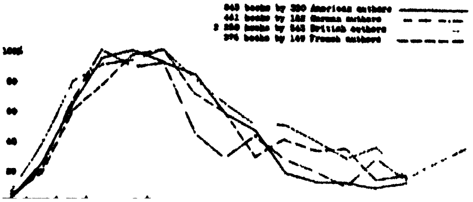

FIG. 7. CHRONOLOGICAL AGES AT WHICH THE MORE NOTED AUTHORS OF FOUR COUNTRIES FIRST PUBLISHED THEIR MORE SIGNIFICANT LITERARY WORKS. THIS GRAPH IS BASED UPON DATA FOR 149 FRENCH AUTHORS, 152 GERMAN AUTHORS, 543 ENGLISH AUTHORS AND 330 AMERICAN AUTHORS.

Fig. 7 sets forth for four national groups the average number of books that were published per five-year interval when the data are obtained from truly selective bibliographies.[15, 16, 17, 18] Fig. 7 presents graphically the following data:

Nationality of authors	Source of data	No. of books	No of authors	Average no. of books per author
American	Fullerton	843	330	2.55
German	Priest	461	152	3.03
British	Ryland	2,250	543	4 14
French	Butler	376	149	2.52

Each of the bibliographies employed for obtaining the data set forth in Fig. 7 contains an average of less than 5 books per author. Notice that the resultant age curves are fairly consistent for the four national groups.[19]

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[15] B. M. Fullerton, "Selective Bibliography of American Literature: 1775–1900." New York: William Farquhar Payson. 1932. Pp. xii + 327.

[16] G. M. Priest, "A Brief History of German Literature." New York: Charles Scribner's Sons. 1909. Pp. xii + 366.

[17] Frederick Ryland, "Chronological Outlines of English Literature." London: Macmillan and Company, 1910. Pp. xii + 351.

[18] K. T. Butler, "A History of French Literature." London: Methuen and Company, Ltd., 1923. In two volumes. Pp. xiii + 496; viii + 395.

[19] The data for the British authors were subdivided into four groups on the basis of the periods when the authors were born. The curves

LESS DISCRIMINATING BIBLIOGRAPHIES

What type of curve is obtained when data are secured from bibliographies that are much less selective? Fig. 8 sets forth data that were obtained from four bibliographies which vary widely in the degree to which they are selective.[20, 21, 22, 23] In each instance, the more selective the bibliography, the more rapidly does the resultant age-curve descend after the age interval 40 to 44 is reached. One can easily understand why the curves that picture a larger number of books per author tend to remain high at most age levels. It requires many years of effort to produce large numbers of books. But why do the peaks of production for the more carefully selected titles occur so consistently *before* rather than *after* age 45?

QUALITY VERSUS QUANTITY

Some may wonder whether the differences in the shapes of the curves of Fig. 8 may not be due in part at least to the fact that different groups of authors wrote the books that were used as a basis for constructing the curves. The available data seem to indicate that the foregoing explanation is inadequate. For example, in Fig. 9 the solid line sets forth the chronological ages at which 152 German authors first published 461 of their best works, the latter being found in a highly selective bibliography which lists an average of only 3.03 works per author. The dash line in Fig. 9 presents, on the other hand, the ages at which *the same 152 German authors* first published an aggregate of 2,935 literary works,[24] the average number of works per author being 19.31. In Fig. 9 the dash line might be said to reveal *quantity* of production; the solid line reveals on the other hand *quality* of production.

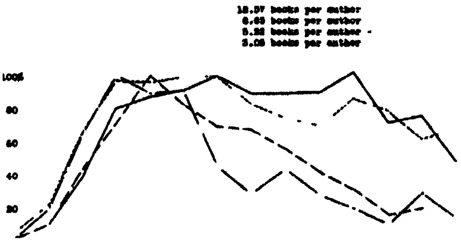

FIG. 8. AGE CURVES OBTAINED FROM BIBLIOGRAPHIES WHICH VARY AS REGARDS THE EXTENT TO WHICH THEY ARE SELECTIVE.

In Fig. 9 the curve for the production of the better books ascends slightly more slowly than does the curve for the aggregate. This phenomenon suggests the ex-

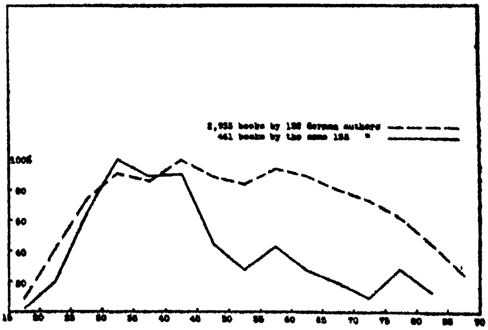

FIG. 9. THE SOLID LINE SETS FORTH THE AVERAGE NUMBER OF THEIR BEST WORKS THAT WERE PUBLISHED BY 152 GERMAN AUTHORS DURING EACH FIVE-YEAR INTERVAL OF THEIR LIVES. THE DASH LINE REVEALS HOW THESE SAME 152 GERMAN WRITERS CONTINUED TO PUBLISH.

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that were constructed with each of the four sets of data exhibited marked similarity both to the curves that are shown in Fig. 7 and to one another. It seems evident that the data which were employed for constructing the age-curve for the British authors possess internal consistency.

[20] G. M. Priest, "A Brief History of German Literature." New York: Charles Scribner's Sons. 1909. Pp. xii + 366.

[21] Stanley J. Kunitz, "Authors To-day and Yesterday." New York: The H. W. Wilson Co., 1933. Pp. vii + 717.

[22] Paul Harvey, "The Oxford Companion to English Literature." Oxford at the Clarendon Press. 1933. Pp. viii + 864.

[23] S. L. Whitcomb, "Chronological Outlines of American Literature." New York: The Macmillan Co., 1906. Pp. xi + 285.

[24] Wilhelm Kosch, "Deutsches Literatur-Lexikon: Biographisches und Bibliographisches Handbuch." In Zwei Bände. Halle: (Saale) Max Niemeyer Verlag. 1927.

istence of a brief practice period. During this practice period books are being written, but posterity seems not to regard these earliest productions as great books. It seems apparent also that, although the 152 German authors continued to publish during their later years,[25] their later works are less likely to be included in highly selective bibliographies than are the works that were published by them at somewhat younger ages

In Fig 10 a similar situation is found to exist. In this figure the solid line presents the chronological ages at which 65 contemporary British and American authors first published 154 starred books The data used in the construction of Fig 10 were obtained from two books by Manley and Rickert[26] [27] of the University of Chicago These compilers have indicated the contemporary books which they regard as most outstanding by means of stars or asterisks The dash line in Fig 10 sets forth, for the same 65 contemporary authors, the chronological ages at which they first published 1,277 works; the latter figure includes both starred and unstarred publications. Fig. 10 suggests once again that the very best examples of belle lettres are likely to be published during a somewhat narrower span of years than are works of lesser merit.

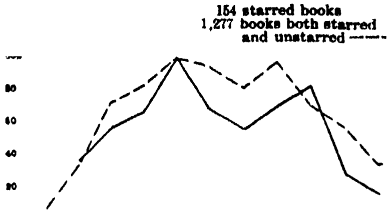

FIG. 10. AVERAGE NUMBER OF "STARRED" BOOKS (AND AVERAGE NUMBER OF BOTH STARRED AND UNSTARRED BOOKS) PUBLISHED BY CONTEMPORARY BRITISH AND AMERICAN AUTHORS DURING EACH FIVE-YEAR INTERVAL OF THEIR LIVES. DATA FROM MANLEY AND RICKERT

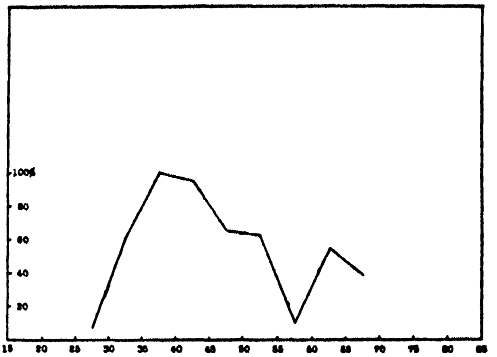

FIG 11 DATA FOR THE 25 MOST INFLUENTIAL BOOKS PUBLISHED SINCE 1885. ESTIMATES MADE BY EDWARD WEEKS, JOHN DEWEY AND CHARLES A. BEARD. EACH BOOK HAS BEEN COUNTED AS OFTEN AS IT WAS LISTED.

THE MOST INFLUENTIAL BOOKS SINCE 1885

Separate lists of what they believe to be the 25 most influential books that have been published since 1885 have been prepared recently by E. A. Weeks, by John Dewey and by Charles A. Beard.[28] When each book is credited as many times as it was endorsed by the three judges, Fig 11 is obtained. In Fig. 11 the peak occurs from ages 35 to 39 inclusive.

CONCLUDING REMARKS

The chronological ages at which men have most frequently published books that are good and that are permanently great can be ascertained by assembling data, separately for the various age groups, and by scrutinizing the performance record of each age group. In making such a study it is desirable to utilize

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[25] This finding suggests that the decline in the quality of their writing at the older age levels was not due to obvious bodily infirmities or to gross physical weakness.

[26] J. M. Manley and E. Rickert, "Contemporary British Literature." New York· Harcourt, Brace and Co., 1928. Pp. 345.

[27] J. M. Manley and E Rickert, "Contemporary American Literature." New York: Harcourt, Brace and Co., 1929. Pp. viii + 378.

[28] Edward A. Weeks, *The Atlantic Monthly*, 155: p. 28, 1935.

TABLE I
SUMMARY OF FINDINGS WITH REFERENCE TO THE PRODUCTION OF BEST BOOKS

	Data used in	Source of data	No. of books	No of authors	Average books per author	Median age	Mean age	Standard deviation	Years of maximum productivity
———— ——	Fig 1	Dickinson	224	101	2.22	43.50	43.51	10.03	40–44
—————	Fig 2	Dickinson	111	54	2.06	43.00	42.34	9.60	40–44
— - — - —	Fig 2	"	224	101	2.22	43.40	43.51	10.03	40–44
— — — —	Fig 2	"	366	169	2.17	43.96	44.10	11.15	45–49
-- — -- —-	Fig 2	"	532	265	2.01	43.80	44.45	11.40	40–44
———— —	Fig 3	Dickinson	241	241	1.00	44.50	44.62	11.25	35–39
— — — —	Fig 3	"	80	80	1.00	42.93	44.19	10.28	35–39
—————	*Fig 4	Weeks	60	47	1.28	42.20	42.25	9.60	40–44
— ————	*Fig 5	Browne	97	101	0.96	41.50	43.94	13.98	35–39
—————	Fig 6	Townsend	337	203	1.66	44.09	45.11	12.35	35–39
— -- — —	*Fig 6	Townsend	396	285	1.39	42.88	44.76	10.80	40–44
—————	Fig 7	Fullerton	843	330	2.55	39.39	40.63	11.00	35–39
- — - — -—-	Fig 7	Priest	461	152	3.03	38.90	40.31	11.73	30–34
- - - - - - -	Fig 7	Ryland	2,250	543	4.14	41.47	42.03	13.20	40–44
— — — —	Fig 7	Butler	376	149	2.52	41.19	42.66	12.30	40–44
- —— - ——	Fig 8	Priest	461	152	3.03	38.90	40.31	11.73	30–34
— — —	*Fig 8	Harvey	673	122	5.52	41.33	42.92	12.45	35–39
- - - - - - -	*Fig 8	Whitcomb	1,157	134	8.63	44.28	46.34	14.85	45–49
——— — ——	Fig 8	Kunitz	2,191	118	18.57	41.59	43.80	11.70	65–69
— - - ———	Fig 9	Priest	461	152	3.03	38.90	40.31	11.73	30–34
— - -- --	Fig 9	Kosch	2,935	152	19.31	44.61	45.25	16.50	40–44
—————	*Fig 10	Manley and Rickert	151	65	2.37	42.92	44.25	10.70	40–44
— — -- —	*Fig 10	" " "	1,277	65	19.65	43.50	45.60	13.85	40–44
——— ———	*Fig 11	Weeks	71	46	1.54	44.00	44.40	9.65	35–39

* Data for some living authors are included in these curves

the evaluations of specialists, of literary critics and historians. In the investigation that is reported herein, the writer has adhered to the foregoing postulates. He has accepted the judgment of specialists who published their evaluations under their own names and who must therefore have felt some responsibility for making just evaluations.

The assembled data suggest that literary masterpieces of the first rank have been published most frequently by men who were not over 45 years of age at the time their best books appeared in print. For six age-curves that are based upon highly selective bibliographies maximum productivity occurs at age 37; for eight other such curves the peaks occur at age 42. But the foregoing figures are based upon the dates on which best books were first published. Books must be written before they can be published. And an author sometimes encounters difficulty and delay when trying to find a publisher. The dates of first publication therefore fail to tell the chronological ages of the authors at the time they were writing their best books. Because of the prodigious labor that such a task would entail, the present writer has not attempted to ascertain dates of composition for all the best books that have been studied herein. However, a few dates of composition are available. Although fragmentary, these data make it seem highly probable that best books have been *written* most frequently by authors who were still in their *thirties*.

There are of course many exceptions to this latter statement, and there seems

TABLE II

AVERAGE NUMBER OF CONTRIBUTIONS PER FIVE-YEAR INTERVAL*

	Chronological age interval														
	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89
Fig 1..		008	034	.049	073	*100*	091	.056	.043	025	.012	.005	.—	.015	
Fig 2..		007	030	064	.057	*105*	097	.057	024	.012	.010	.—	.—	.034	
Fig. 2..		.008	034	049	.073	*100*	091	.056	043	025	012	.005	—	.015	
Fig. 2..		.007	.039	052	.067	081	*082*	.051	.042	.032	.028	.007	.—	.017	
Fig 2..		.007	.030	052	.063	*.075*	.072	044	039	.033	.027	.011	.003	011	
Fig. 3..		003	014	026	*.036*	034	.036	.021	.022	.015	015	005	.—	.006	
Fig. 3..		003	010	020	*046*	041	.035	.020	019	.016	.009	.006	.—	.—	
Fig 4†.		.004	021	034	040	*.081*	055	011	.019	.024	015	—	.—	.—	
Fig 5†.		004	.014	.036	*038*	023	031	.025	.009	020	.020	.011	010	—	
Fig 6..		007	.024	037	*.063*	.055	.056	042	.029	.038	017	.013	020	.018	057
Fig 6†.		—	018	029	060	*068*	062	055	.052	.043	.059	.058	.021	.—	
Fig 7..	001	023	060	092	*097*	089	081	055	045	018	011	010	.007	.009	
Fig 7..	003	025	081	*124*	110	.113	056	.035	.053	033	024	011	035	.016	
Fig. 7..	007	050	106	123	128	*.137*	.111	087	069	.068	.054	.037	047	019	.033‡
Fig 7..	003	016	.055	072	090	*093*	.066	054	.027	037	.031	032	.012	015	
Fig 8..	003	025	.081	*124*	110	.113	056	.035	.053	033	.024	011	.035	.016	
Fig. 8†.	003	023	097	.161	*227*	188	157	.151	.125	.092	069	034	.043	—	
Fig 8..	015	055	158	232	230	.236	*239*	.198	.178	.164	.206	.187	.145	.157	.118
Fig 8†.	—	087	331	683	738	771	851	.760	.760	702	*861*	606	636	.400	
Fig 9..	003	025	081	*124*	110	.113	056	.035	.053	033	.024	.011	.035	016	
Fig 9..	045	211	.383	.475	448	*522*	.463	.439	.490	463	.420	.383	317	.226	.125
Fig 10†.			040	062	075	*111*	.077	061	081	.006	.035	.022			
Fig 10†.		.055	246	542	617	*752*	.716	619	.733	.536	.435	261	.304	.375	
Fig 11†.			004	044	*072*	068	047	045	.006	040	.027	.—	.—	—	

* The peak of each statistical distribution is italicized
† Data for some living authors are included in these distributions
‡ The average for the succeeding five-year interval, namely, for ages 90 to 94 inclusive, is .050.

to be no fixed age limit beyond which outstanding literary work can not be done. Perhaps it will be better for us to discard the habit of thinking in terms of age limits or even in terms of average ages. The creative years may be envisaged best not by reference to a simple average or to an age-range but rather by study of age-curves (or statistical distributions) which reveal trends and probabilities rather than fixed age limits.[29] Certainly, some writers have produced great books at relatively advanced ages. However, this phenomenon is not a frequent occurrence, and those who are much impressed by the fact that the second part of Goethe's "Faust" was first published when Goethe was more than 80 years of age should recognize that such an occurrence is not at all typical but most unusual.[30]

In attempting to interpret the age-curves that are presented herein the present writer has questioned several experts whose judgment should merit careful consideration. A copy of Fig. 9 was sent to an eminent literary historian. The historian was asked whether it did not seem preposterous that in Fig. 9 the peak for quality of production appears earlier than the high point for quantity of production. In commenting upon Fig. 9 the literary historian stated that he was not surprised at this finding. On the contrary, he expressed surprise at the surprise of the present writer. His statement follows:

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[29] Unfortunately, only a very small number of such age-curves are available.

[30] Although Part II of Goethe's "Faust" is cited frequently as proof of the fact that men of advanced years are capable of producing excellent literature, it is worthy of mention that Part I of "Faust" is more often *quoted* as an example of excellent writing. Moreover, the following remark by a widely known scholar whose name appears in the bibliography of this article is of interest. "Many literary historians think that the works which Goethe wrote between 1770 and 1780 [ages 21 to 31] were never equalled by him later, an opinion which can be defended effectively."—Unpublished personal communication.

> The surprise which you express in your letter of Feb. 14th "that *quality* of output precedes *quantity* of output" surprises me in turn. I can easily believe that this finding is a valid one. . . . It is normal and natural that a young man has much more mental and physical energy than later on in his life. He often feels himself the bearer of an epoch-making message and therefore proceeds to the expression of his message with all the intense conviction and concentration of a gifted youth. Very soon, however, that fire dies down, at least to some extent, and his later works reveal perhaps that he was a man of a single message, in any case that he has grown steadier, more restrained and consequently more prosaic and probably duller. . . . I have come to this conclusion largely on the basis of my study of biography.

Do the decrements at the older chronological age levels imply a corresponding decrement in the *ability* to write best books? There are at least two excellent reasons for rejecting this hypothesis. In the first place, the *post hoc ergo propter hoc* fallacy should be avoided. Secondly, we are dealing here not with sheer ability but with actual concrete performance. It seems obvious that outstanding potential ability must be present in the individual who produces literary masterpieces. It is by no means clear, however, that failure to produce is due necessarily to inability to produce. We know only that, for some one or more reasons, the noted authors, although they continued to write, failed to produce best books as frequently at the older as at the younger age levels. Probably most students of psychology would agree that such a complex behavior as the production of best books is due to numerous causal factors. The decrement at the older age levels might be due therefore to any one or more of a very large number of possible causes.[31]

For most readers it will not be necessary to state that psychology has no fault to find with the gifted writers because these writers failed during their later years to maintain the quality of their writing Students of human behavior are interested primarily in acquiring a better understanding of their subject-matter. With this end in view they endeavor to assemble trustworthy and significant behavior data. It would be puerile for psychologists to find fault with the behavior which they are seeking to understand. Probably no psychologist would assert that authors exist for the sole purpose of producing best books. Certainly, the present writer harbors no such belief.

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[31] The fact that most of the authors continued to write during their later years indicates that they had not lost all desire to write. On the other hand, they may not have been maximally motivated during their later maturity. Possibly something akin to the law of diminishing returns may have been operating at this time. *Cf.* in this connection Thorndike's excellent discussion of why adults often fail to continue to learn after they have attained adulthood. See E. L. Thorndike, E. O. Bregman, J. W. Tilton and E. Woodyard, "Adult Learning." New York: The Macmillan Co., 1928. Pp. x + 335.

NATURAL HISTORY EXHIBITS AND MODERN EDUCATION

By Dr. ROBERT CUSHMAN MURPHY
AMERICAN MUSEUM OF NATURAL HISTORY

LORD GREY of Fallodon once remarked, during a visit to the American Museum of Natural History, "I would gladly cross the ocean for the sake of four hours in this institution"

The enthusiastic comment relates obviously to the museum's exhibits, which, although far from constituting the whole organization, take first place in the conception of any public museum. From an analysis of the budget of the American Museum throughout several years, it appears that two thirds of every dollar spent go toward the creation and maintenance of exhibits, the remaining third being divided between research and other activities

It scarcely needs pointing out that contemporary museums face wide-spread competition in their own field of exhibition. We live in an age that broadcasts its messages largely by the graphic method—by display in one form or another Fairs, visual demonstrations in schools and, perhaps most of all, the design and content of what is shown behind an infinity of smart shop windows, all present challenges that the museum must take into account. Exhibits planned in the year 1869, when the American Museum was founded, could hardly interpret the natural history of to-day.

What, then, are the essentials in method for a modern natural history museum? A great financier, who was also one of the founders of the American Museum, once made a classic reply to a question put to him in court by stating disarmingly that character is the basis of credit.[1] The basis of museum exhibits might be defined, slightly less tersely, as scholarship in conception and technique in execution. Scholarship must rest, of course, with the scientific staff. As regards technique, it is well known that the exhibits occupying so many acres of floor space depend upon the talent and painstaking labor of a long roster of trained men and women, who include painters, sculptors, engineers, workers in metal, blown glass and various plastic materials, tanners, taxidermists and artisans possessed of phenomenal capacity to make faithful copies or scale models of all manner of natural objects. At a recent meeting in the office of the mayor of New York, attention was called to the fact that the city's natural history museum has a much larger working force than a great sister institution devoted to the fine arts. In eight words of one syllable, the director of the American Museum precluded any possible implication of an unjust disparity. His comment was, "They buy their art; we must *make* ours."

If one were to analyze the character of exhibits in a natural history museum, a trifold division might be made, although the border line separating any of the three would be necessarily somewhat vague. In the first place, there are on view many objects, or representations of normal phenomena, which are primarily of intrinsic interest. They are in themselves perennially exciting and stimulating in varying degree. A few random examples of such are the following:

The bench mark of the United States Geological Survey which indicates to a fraction of second the geographic position of a particular point on the surface of the globe, and its altitude to the hundredth part of a foot above sea level.

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[1] J. Pierpont Morgan, 1837–1913.

The north and south polar sledges of Peary and Amundsen, respectively.

The cross section of the California Big Tree. (The historical commentary forming part of this exhibit brings it also into the third group, discussed below)

The skeleton of Brontosaurus, mightiest of dinosaurs.

The model of the Blue Whale, a present-day mammal far larger than any known prehistoric creature.

The 579 pound shell of a mollusk, Tridacna.

The reconstruction of the Dodo.

The Easter Island stone figure

The tatooed Maori heads, which at once repel as grim trophies of barbarism and attract as examples of amazing design.

The Drummond amber.

The Cape York meteorites.

All such factual exhibits as these arouse a host of unguessed ideas that reverberate through the corridors of countless minds. The effect of each is, however, unplanned and unpredictable, and each is shown chiefly for its own sake. Can such exhibits be called static? Far from it, partly because there are no known limitations to the responses aroused by such unelaborated expressions of truth and, furthermore, because there are endless successions and generations of new eyes to perceive them.

A second group of museum exhibits might be classified as of primarily *timely* interest, that is, as connected with current news. At intervals of years, the reservoirs supplying water to the metropolis become infested with a microorganism that imparts a harmless but unpleasantly fishy odor to the indispensable fluid that flows from our taps. Human memory is short, besides which there are hundreds of thousands of newly arrived or newly grown-up urban residents to become alarmed. The press, fortunately, merely has to consult its old files in order to explain the recurrent circumstances. The glass model of *Synura uvella,* a colonial flagellate enlarged ten-thousandfold, is brought from its systematic position in the Darwin Hall, is given a temporary place of honor near the main entrance of the museum and is inspected by thousands of visitors, who at other times might pass it by with no more than a casual glance. Their edification, incidentally, relates not merely to the transitory phenomenon of fishy drinking water, but also to rhythmic cycles in biological productivity, to the power of infinitesimal specks to multiply into cubic miles of protoplasmic jelly, and to the microcosm of life whose universe may be a drop of water.

Many other exhibits of the moment have given evidence of their importance. The news that the average citizen reads in his morning paper sometimes provides the museum with opportunities not attainable through any deliberate campaign, regardless of the energy and funds put into it Such are to be seized upon as educational windfalls. Nor has the opportunity yet been more than barely tapped, for additional temporary exhibits might well be tied up with such manifestations of an outraged nature as the great river floods of 1937. How more effectively could we spread a knowledge of the projects by means of which Americans must repair the damage they themselves have wrought, if civilization is to endure in this potentially richest of temperate continents?

Finally, we come to a consideration of the class of museum exhibits that involves the major thought of members of the staff, namely, those planned to impart to visitors an organized system of information. In these the principle to be elucidated transcends the interest of the objects themselves. The latter are bricks in the structure, and the stated aim is to build a museum of ideas rather than of things. While these are usually known as "permanent" exhibits, many of them are properly subject to constant change. They are in essence dynamic, and, as the emphasis in various branches of natural history has transformed throughout the decades, so has their museum interpretation correspondingly developed. To the complaint of a member that, during her somewhat infrequent visits to the American Museum, the special halls that she wished to inspect had an aggravating way of being "under repair," the director replied that her charge was a compliment. Would she, he asked, like to believe that her museum was a frozen institution, and that cases arranged in 1930 could do full justice to the status of knowledge five years later?

The American Museum's interpretative exhibits range from very simple associations of objects or organisms to others that might prove within the grasp only of persons of considerable education and discernment. *Persicos odi, puer, apparatus!* Museum exhibits should certainly never be more abstruse or complex than absolutely necessary, but neither should they be limited to the primer stage of science. The latter restriction would be as unreasonable as confining a musical program to the level of the poorest tastes in the audience. We must provide in our museum plan for the highest order of intelligent and inquiring laymen, including those whom William James would designate as the truly "tough-minded."

First and most widely advertised among natural history displays illustrating an association of ideas are, of course, the habitat groups. Once installed, these are rarely altered, although many have been replaced. The conception of such exhibits did not originate in this country, but they have undergone here their fullest development. Incidentally, the earliest example in the United States—a family of robins nesting in a spray of apple blossoms—forms a still effective item in the American Museum. It is a far cry, indeed, from such a simple installation to the great exhibits of the Coral Reef, the Gorillas of Mount Kivu, the Navajo Indians and their ceremonies, or the fifteen miniature earth-sections in the form of block models which reveal the physiography and geologic history of as many parts of North America.

The aims of a habitat group go beyond the reconstruction of a "pretty picture" transferred behind glass from the outer world. Its purpose ought also to be ecologic, that is, it should elucidate natural interrelationships between organism and organism, and between all and the physical environment. It may deal further with a combination of many other things —with the life story of both plants and animals, or even of minerals which also have birth, existence and death, with geographic zones, conservation, biological adaptation, with history, folklore and a wealth of other ideas. Let us cite examples:

Perhaps more visitors to the American Museum ask to have the nightingale pointed out than is true of any other single bird. They can now be best satisfied through the habitat group of English bird life. Here, among the beeches, holly, gorse and bluebells of the New Forest, sits the storied singer, along with cuckoo and skylark, chaffinch, wood pigeon, rook and jackdaw and a host of others which belong to us by the divine right of literary inheritance. The exhibit is, indeed, a magic casement. The inquiring visitor may learn, furthermore, the importance of vast and ancient trees (which we have so wantonly eliminated from much of our own countryside) with relation to the cubic environment that birds are capable of filling. Here, then, is at least one reason why England has a larger bird population than is to be found in most other temperate lands. One can learn, too, while looking at a British titmouse scarcely distinguishable from our American chickadee, something of the intimate relationships among northern circumpolar forms of life which claim Old and New World alike as their home. At the dedication of this New

Forest group, a delightful suggestion was made by Sir Gerald Campbell. How happy it will be for international neighborliness, he remarked, if among the generations of Americans who will gaze into this Hampshire landscape, with its birds of Chaucer and Shakespeare and Keats, there is now and again one who will be moved to say to himself, "I must cross the ocean soon and find out whether Englishmen are worthy of their birds."

From the universal charm of northern springtime, let us turn to the macabre and unfamiliar fascination of the bottom of the ocean. Two thousand fathoms deep, in the inner sanctum of the hall of fishes, silvery ratfish glide in and out through rotting flesh along the backbone of what was once a whale. What may the least tutored of visitors really carry away from this and adjoining exhibits and their labels? That eternity is as black as pitch in the abyss of the waters; that eyes may avail, nevertheless, because some living beings have evolved their own lanterns of cold light; that all primary sustenance of the depths rains down from layers far above, and that the bottom population is made up wholly of the predatory and cannibalistic; that a permanent temperature of melting ice is of no moment to animals which need no insulation because they have no fixed bodily warmth to maintain; that the enormous and notorious pressures are purely relative and in essence illusory, because the only requirement of well-being, even for the most delicate of organisms, is that the internal pressure of its tissues be equal to that of the medium outside.

But habitat groups, however impressive, can not stand as the final goal of exhibition. With the Akeley African hall nearing completion and the Whitney memorial hall under construction, it is likely that the American Museum has already attained the ultimate in elaborate representation of nature in life-size scale. Similar exhibits can be built, but it is hard to believe that the result can be appreciably bettered. The groups now on view or projected no doubt justify their cost and space for reasons already indicated and, even more particularly, because in many instances they alone can provide posterity with realistic glimpses of a primitive world that will be no more. A few of the assemblages of mounted birds and mammals already share at least one thing in common with exhibits, for instance, such as the matchless weaving of the Incas; animals and textiles alike may be said to represent something that is finished, something that can never be replaced; it is only in museums that future generations may seek them.

The need for distinctly new approaches, even in the making of habitat groups, has long been recognized, as witnessed by the American Museum's Rotifer exhibit, which brings to the naked eye the once unimaginable life of a cubic centimeter of pond water enlarged a million times! Into other and even more dynamic rôles of expression, however, the trend in exhibits is fortunately leading us. The "things" shown become increasingly units in a diagrammatic whole. Selected, rather than random, facts are marshalled to point out the significant and omit the trivial. Best of all, there is nothing fixed or sacrosanct about such exhibits; change rather than permanence is their accepted destiny; an arrangement may be scrapped and recast as rapidly as new truths warrant the step.

The exhibits of fossil vertebrates, to choose an example dating from the early years of the American Museum, have always comprised a constantly growing synthesis of ideas, becoming clearer and more meaningful as the strata of past worlds have yielded up their treasure. Little by little the fragments have developed into such wholes as those outlining the evolution and distribution of horse, camel, rhinoceros, titanothere.

The halls are further accented by almost overpowering presences—the rearing skeleton of Tyrannosaurus, the relief model of Baluchitherium. And, finally, the several parts are knit together by the mural paintings which garb primordial bones with the vestments of life and reality. It would be hard to estimate the influence of this single department of the museum upon the outlook of modern man; suffice it to say that such a commonplace vernacular word as "dinosaur" was a highbrow term only a generation ago.

To single out among exhibits a few additional examples that serve particularly well the purpose of current scientific exposition is unfair to a much larger number which must here go unmentioned. It is safe to guess that an independent selection might result in an entirely different choice. The following are a few, listed individually or collectively, large or small in their respective scopes:

The models in the Morgan memorial hall which illustrate the principles of crystallization.

The exhibits which explain the dating of geologic time by plotting the relative thickness of clay varves deposited seasonally during glacial periods. With these might be linked kindred archeological demonstrations of how prehistoric man-made structures have likewise been dated through the study and correlation of annual growth-rings in their ancient timbers.

The several exhibits dealing with the biology of insects and of reptiles and amphibians. These not only explode numerous popular misconceptions but also define with all but wordless simplicity a number of the modes, devices and causal sequences in nature which, under less lucid demonstration, are often difficult to convey or comprehend. Some of these exhibits demonstrate, moreover, the entirely feasible use of living organisms for certain museum purposes.

The introduction to human and comparative anatomy, which begins with the sun and the use of its energy by living beings, and progresses by logical stages to the function of the human brain and the physiology of mental processes.

Numerous ethnographic exhibits, which at once reveal the accomplishments of past or primitive peoples and serve as sources for current art and design or as stimuli which bear in some other way upon contemporary civilization. Here, indeed, are exhibits of ideas which show the place of social habits, on the one hand, and of geographic environment on the other, in determining human culture; which show—to pick at random—the iron technique that distinguishes African Negroes from all other savages; the models that point out the high efficiency in practical navigation attained by the South Sea Islanders; the origin and growth of Central American civilizations wholly independent of those in the Old World.

But, beyond all present accomplishments, we are surely at the threshold of a thousand fresh opportunities in museum development. The exhibition value of many recent discoveries in natural history can scarcely be overemphasized Where in any museum is there a scale of the universe, or more than passing reference to what has been learned about the chemistry of living substance? Where can we find in graphic form the fundamentals of life in the sea, the principles of animal and plant associations, the physical factors regulating life in the desert or the jungle? Yet such matters can be reduced to terms of simplified description far better in museum exhibits than in books. Furthermore, where in museum treatment is shown the relation of sun-spots and climatic cycles to the growth of living communities, both plant and animal? Or what regulates the size and the length of life of organisms, or the distribution in nature of color and of what we call beauty?

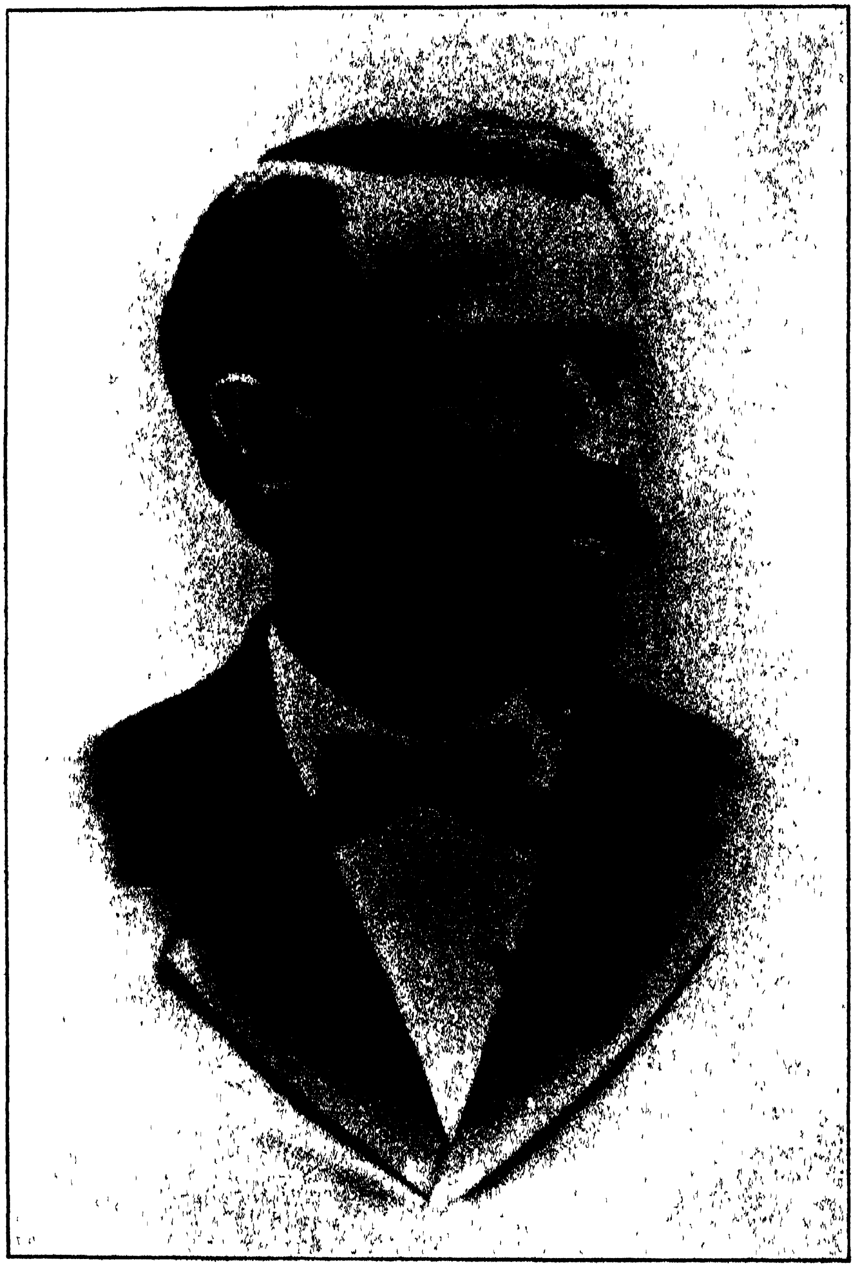
Contemporary study of behavior, aided by the experimental resources of chemistry and biophysics, is outlining a startling and illuminating picture of the animal mind. At the same time, mechanical devices, such as the photoelectric cell, sound photography, "robot-voices"—perhaps even television—are supplying us with able and equally up-to-date means of demonstrating the findings. The halls of natural history museums should and will include ingenious exhibits that can tell us much about how

the external world looks in color, form and the relative importance of its component parts, when viewed by the eye of a bee, a bird or a fox. Related exhibits might show how animals necessarily react with respect to the rhythmic cycle of their endocrine glands. An important supplementary place in exhibition cases will be required, of course, for revealing the experimental studies through which such confident yet seemingly mystical conclusions have been reached by prying man.

Most natural history museums have elementary exhibits dealing with the science of genetics, but where can we look for popular demonstrations of the enormous recent advances in that field, including the subject of induced mutations? Discoveries relating to the biological value of light and of climatic change have found their way into college courses, but thus far only to a negligible extent into museum cases. Many museums have pretty caves among their exhibits, for example, but not yet an explanation of how cave faunas have been moulded by the absence of light. Creditable museum records of early man are numerous, but where can we yet see dramatized the steps through which the glacial period produced modern man? What is intelligence, and does an amoeba possess it? How do insects feel and think? How has man come by his instincts; how and to what extent are these controlled by his newer and rather unstable endowment of higher discrimination? The answers to all such questions lend themselves admirably to museum methods.

All this and much more, indeed, must soon come to pass unless the natural history museum is to fail in fulfilling its service as a modernized beacon lighting the way between the discovery of truth and its widest possible dissemination.

To-day it is increasingly evident that as preparation for happy and well-ordered living the sciences have crowded their way in among the old "humanities" of the classical tradition. Leaving aside every vocational or so-called practical bearing, ignoring even the rich satisfaction that knowledge of the green and vibrant world of nature confers in this out-of-door age—even beyond all this we know that as education which must prepare for an understanding of everyday life, of social organization, of government, the old aspects of truth have become insufficient. The "man in the street" must add to his fund of information at least a minimum knowledge of modern physics and of the miracles of protoplasmic behavior if he is ever to gain an inkling of what life and the cosmos are all about. From the department of astronomy to that of the science of man, natural history museums should still aspire to share and to lead in the great campaign.



Courtesy of C. E. Dutton

CLARENCE EDWARD DUTTON

C. E. DUTTON—EXPLORER, GEOLOGIST, NATURE WRITER

By Dr. WALLACE E. STEGNER

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THE discovery and exploration of the Plateau Province of the Southwest, comprising southern Utah, northern Arizona and portions of eastern Colorado and New Mexico, was the work of many men, most famous of whom are government men likes Ives, Wheeler and Powell, and the "Mormon Leatherstocking," Jacob Hamblin. As is frequently the case, however, men later in time, and with less right to the title of explorer, have left as prominent marks of their personalities and work upon the country as its actual discoverers. The name of Clarence Edward Dutton, for example, is undoubtedly as well known in the history of the opening of the Plateau Province as that of even Powell himself, and yet Major Dutton apparently never discovered anything for the first time.

There are several reasons for Dutton's reputation. In the first place, his work led him, from 1875 to 1887, to five different spots which later became national Parks. What Muir is to Yosemite, Dutton is to Zion and the Grand Canyon. Although other men, notably Ives and Powell, had written interesting accounts of the Grand Canyon, Dutton's "Tertiary History of the Grand Canyon District," appearing in 1882, was the first detailed and extended account of the great gorge, and contained as well the earliest description of Zion except for Powell's brief thumb-nail sketch in his "Exploration of the Colorado River of the West."

Two years earlier Dutton had written, in his "High Plateaus of Southern Utah," a description of Bryce Canyon that considerably amplified the first picture presented by A. H. Thompson in his report affixed to Powell's "Exploration of the Colorado River of the West." Professor Thompson and F. S. Dellenbaugh, apparently, were the discoverers, having seen the amphitheater while searching for a practicable route down the Colorado in 1872 Dutton probably saw the Paria Amphitheater and Bryce for the first time in 1875, his first year in the Plateau Province.

It seemed Dutton's fate, or fortune, consistently to be the second or third into a field, and yet in almost every case his discoveries and scientific studies of causes and meanings were noteworthy. He was the man who pointed out that Mount Lassen was the last locus of volcanic activity in the United States—a statement since borne out by Lassen's later activity. Although he first saw Crater Lake thirty years after its discovery, he was the first man to bring boats in (a feat of almost insuperable difficulty) for the purpose of plumbing and measuring the lake, and his theory of the origin of the crater has by now become almost a truism. It was in 1885, in the company of William G. Steel, later patron of Crater Lake National Park, that Dutton first saw this spot, and a good part of the next field season was spent in detailed measurements and soundings.

Not content with being involved in the early study and history of Zion, Bryce, Grand Canyon, Mount Lassen and Crater Lake National Parks, Dutton in 1882 spent four months with a pack train among the great calderas of Hawaii with the purpose of studying volcanoes in action before investigating the extinct volcanoes of Oregon and northern California. The resulting monograph, "Hawaiian Volcanoes," although ostensibly a scientific work, is lightened throughout by humorous anecdotes and brilliant descriptive passages, and is one of his most charming books.

Six national parks thus owe something of their history to Major Dutton. All of them, except Mount Lassen, owe him more· the basic geological explanations which are now commonplaces aired by park rangers and guides for the edification of tourists. His books on the Southern Utah Plateaus and the Grand Canyon are still broad foundations for later highly detailed studies, and they remain, despite the passage of more than half a century, the best general works on these regions.[1]

Major Dutton was an explorer of little-known regions and an explorer among little-known facts. Just as his studies among the Plateau regions led to novel geological theories, such as the theory of plural erosion cycles, so the sights which he saw, unusual in the extreme and widely different from the rock formations of other countries, led to a series of unusual names, which, influential as they have been upon the later nomenclature of the region, have been subjected to severe criticism.

Dutton observed, as any one really studying the Grand Canyon and its environs must observe, the striking resemblance which the buttes and towers bear to oriental architecture. Accordingly, when naming points in the gorge, he chose such titles as the Hindoo Amphitheater, the Ottoman Amphitheater, Vishnu's Temple, Shiva's Temple, and so on. It is to Dutton's example that we owe the long series of oriental names that decorate the other canyons, notably Bryce, where the horseshoe is dotted with temples of Osiris and Isis and other eastern gods and goddesses. Thomas Moran followed Dutton's lead in naming the Temple of Set in the Grand Canyon.

Not every one, as has been mentioned, approves of these names. In a letter written just before his death Mr. F. S. Dellenbaugh, a companion of Powell and Dutton on early expeditions and a noted explorer in his own right, had this to say: "I have one grudge against him. He did not believe in applying Indian names to features not already designated—and there were many at that time—as he disliked Indian names. He was thinking, I suppose, of Passamaquoddy and Memphremagog and so on. I argued with him without success, and so he started that series of silly Egyptian and what-not names in the Grand Canyon which are about as inappropriate as any names could be. I don't now remember his argument. He did, however, name Point Sublime, which satisfies me. . . ."

However one may feel in this matter of appropriate nomenclature, one is forced to admit that Dutton's example bore fruit and definitely pinned an oriental atmosphere on the Grand Canyon that will last. The architectural basis for the names is certainly sound, and many of Dutton's other names—The Cloisters, The Transept, Vulcan's Throne, and so on—borrow from other architectures than the oriental ones. He also named a number of the points which jut far out into the gorge and offer the most sublime views. Of these Point Sublime is generally a favorite, as is Point Dutton, named for the geologist. Cape Royal and Cape Final, as well as Hidden Spring and other spots, received their names from him. Occasionally, as in Smithsonian Butte, near Short Creek, Dutton honored a man or an institution in a place name.

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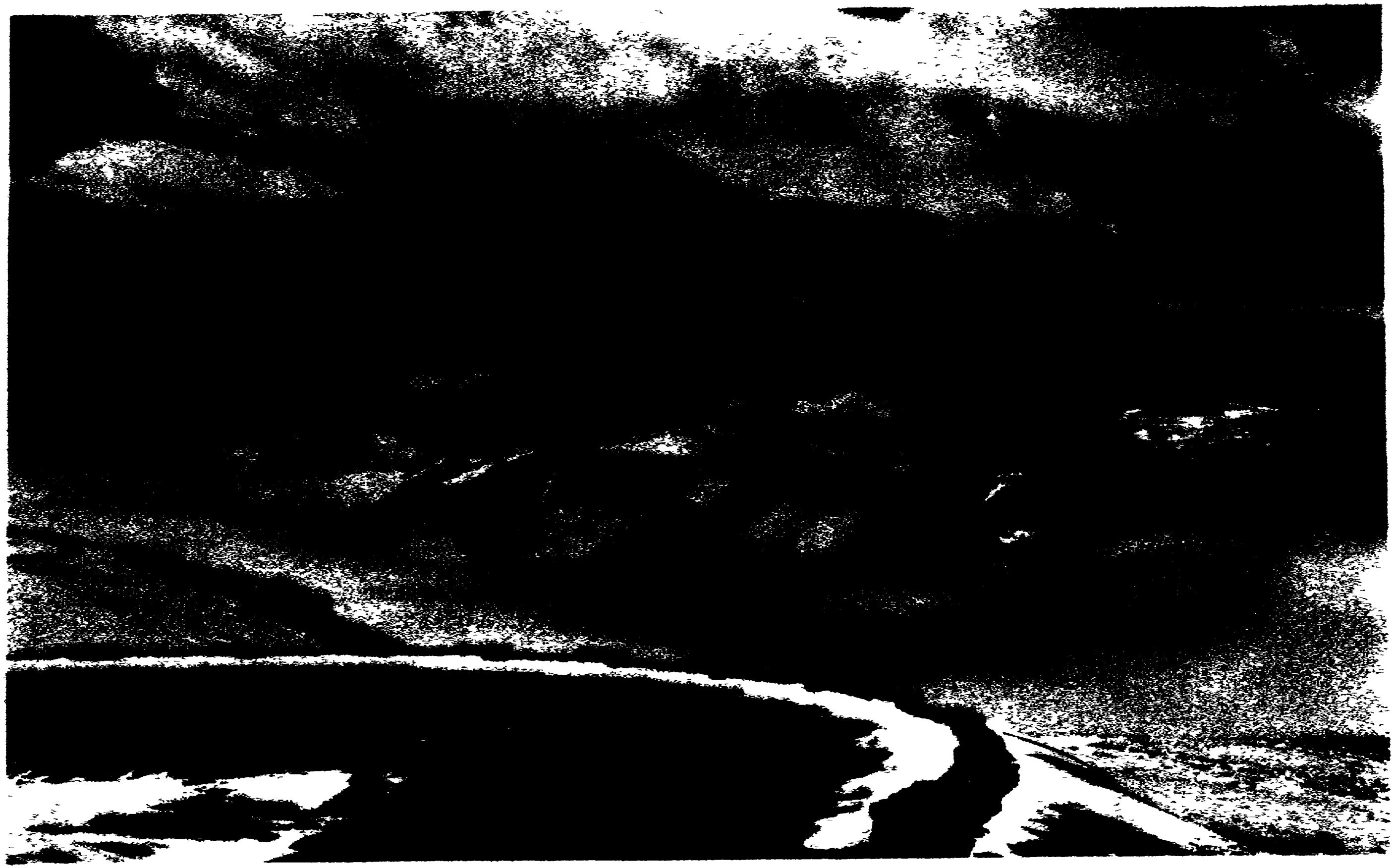
[1] This is not to minimize the work of other early geologists. Dutton himself says, in his "Mount Taylor and the Zuñi Plateau," that the geological results are the product of mutual help among Powell, Gilbert and himself. "All observations and experiences were common stock, and ideas were interchanged, amplified, and developed by mutual criticism and suggestion. The extent of my indebtedness to them I do not know. Neither do they. I only know that it is enormous, and if a full liquidation were demanded it would bring me to bankruptcy."

A full list of spots named by Dutton would undoubtedly be long, but until some detailed study of Utah place names is made, it must remain incomplete.

There is one further reason for Major Dutton's lasting reputation in the Southwest. People recognize in him a great geologist and an important explorer, but they recognize even more immediately a great nature writer.

Natural scenery as grand as that of the Plateau Province is difficult to describe accurately and vividly, as hundreds of inept pen-pictures of the Grand Canyon testify. Yet Dutton, in "The High Plateaus" and "The Tertiary History" paints landscapes unforgettable in their detailed charm. He is master of panorama, as indeed he had to be in a country where the range of vision is sometimes a hundred miles and more. No one has ever caught as well as he the broad vistas of torn and twisted and weirdly beautiful desert and badland. No one has ever fused so completely scientific accuracy and literary charm, as Dellenbaugh has said.

In the last analysis it is not essentially as an explorer that Dutton will be known, although he has certainly some right to the name; it is not primarily as a geologist, though he is one of the great ones of early American geology; it is as an interpreter of landscape, a nature writer who combined sound scientific knowledge with a near-genius in words. One thinks of Muir and Burroughs as comparisons. Dutton was more limited in his field than they, but as fine a writer within his limits and a greater scientist than either. It is his versatility, rather than preeminent abilities in one line, that make his name a byword in the Plateau Province.



TRAIL RIDGE ROAD IN THE ROCKY MOUNTAIN NATIONAL PARK NEAR DENVER

A point of scenic interest for members of the American Association for the Advancement of Science attending the Denver meetings, which were announced in the June issue of The Scientific Monthly. At this point the road has reached an altitude of more than 12,000 feet. In the distance and at the left, above the great cloudbank that obscures Forest Canyon, is Long's Peak, sentinel of Rocky Mountain National Park, with an altitude of 14,255 feet.

THE PROGRESS OF SCIENCE

MEDALLISTS OF THE NATIONAL ACADEMY OF SCIENCES

THE National Academy of Sciences at its seventy-fourth annual meeting from April 26 to 28, 1937, presented four medals in recognition of noteworthy accomplishments in the field of scientific research. The medals were provided from trust funds given to the academy; several of these funds specify that the medal shall be accompanied by an honorarium. The award of each medal is made by the academy in business session on recommendation of the special committee or board in charge of the trust fund. The medal is presented to the recipient at the dinner of the academy at either the annual or the autumn meeting. Before the actual presentation of each medal, the president requests the chairman or other member of the trust fund committee to state briefly the reasons why the recipient was selected for the award.

THE AGASSIZ MEDAL FOR OCEANOGRAPHY

The Agassiz Medal was awarded to Dr. Martin Knudsen, of the University of Copenhagen, Copenhagen, Denmark, "in recognition of his contributions to that field of scientific research, including his report on the hydrography of the Danish *Ingolf* expedition, published in 1898; the preparation of his 'Hydrographic Tables,' published by the International Council for the Exploration of the Sea; his inauguration of standard sea water distributed to other oceanographic institutions by the International Council for the Exploration of the Sea; his invention or improvement of the designs of oceanographic instruments, and his leadership in the development of precise methods in the study of physical oceanography."

Dr. T. Wayland Vaughan, chairman of the Murray fund, which recommended the award of the Agassiz Medal for oceanography to Dr. Knudsen, stated in his presentation speech that

> Progress in many branches of science depends upon the possession of adequate instruments, a body of established physical constants, and proper procedure. The mere recognition of a scientific problem will not solve that problem. Knudsen's first oceanographic experience made him keenly conscious of the fundamental needs of physical oceanography and he set about the development of apparatus and the determination of physical constants. His invention of standard sea water and his refinements of chlorine titration for the determination of the salinity and density of sea water over the entire range of temperatures encountered in the ocean, and the tables prepared by him to embody the results of long-continued investigations, constitute a foundation stone of modern dynamical oceanography.
>
> Knudsen has made a number of designs of oceanographic apparatus, such as a frameless water-bottle, a bottom-samples for hard bottoms and a spectrophotometer. He has also paid fruitful attention to a number of oceanographic problems. His first papers were on the influence of plankton on the quantities of oxygen and carbonic acid dissolved in sea water. His researches in the field of low pressure phenomena in gases are better known to physicists than to oceanographers.
>
> The members of the committee that nominated Professor Knudsen for the Agassiz Medal are happy that the academy approved its recommendation. Professor Knudsen richly deserves the honor conferred upon him.

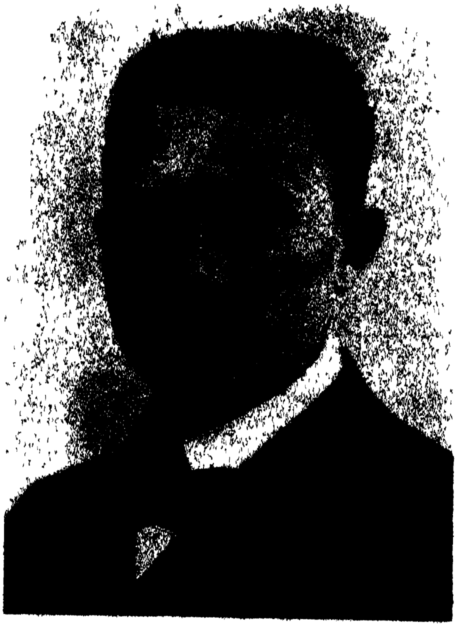
Dr. Knudsen was unfortunately unable to receive the medal in person, and Mr. Otto Wadsted, envoy extraordinary and minister plenipotentiary of Denmark, accepted it gratefully for transmission to Dr. Knudsen through diplomatic channels.

THE HENRY DRAPER MEDAL

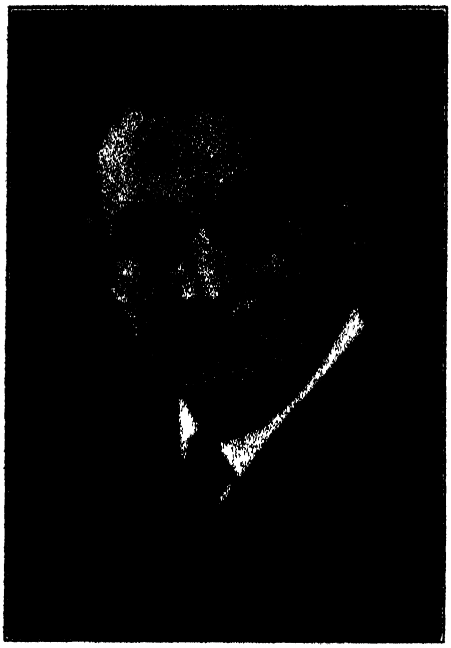
The Henry Draper Medal was awarded to Dr. C. E. Kenneth Mees, director of the Research Laboratories of the Eastman Kodak Company, Rochester, N. Y., "in recognition of his investigations in photographic processes which have given emulsions sensitive to the red and infra-red of the spectrum and made possible the recent great advance in knowledge of this highly important region of the radiant energy of the stars."

The presentation speech was to have been made by Dr. V. M Slipher, chairman of the committee of the Murray fund; but he was unable to be present and Dr. Frank Schlesinger, of Yale University, presented a digest of Dr. Slipher's statement:

> Dr Mees has devoted his life to the development of the theory and the perfection of photographic processes and materials. His early prominent piece of work, "Investigations on the Theory of the Photographic Processes," published in 1907 in collaboration with Sheppard, has since been a classic on the subject. This gave him wide distinction, and he was called to America in 1912, where since then he has been continuously occupied in this field of endeavor at the Eastman Kodak Research Laboratory, of which he has been the director.
>
> Let us recall that at the beginning of the present century it was hardly possible in astronomy to photograph a spectrum range of more than about 2,700 Angstrom units, *i.e.*, from 3,300 to 6,000 A. But to-day fully twice that length of spectrum (*i.e.*, from 6,000 to 12,000 A. in the infra-red) has been added. Much of this great gain has resulted from the development of emulsions and sensitizers at the hands of Dr. Mees. His wide extension of the photographable spectrum into the longer wave-lengths carries even greater scientific importance than might at once be evident, for it brings us knowledge of a vast new portion of the energy of the stars. And this means our knowledge of the heavenly bodies may now be builded upon this broader foundation. In accomplishing these and other advances for photography our medalist has contributed to the general progress of science, as well as to astronomy in particular. Incidentally he has built up the excellent Research Laboratory of the Eastman Kodak Company. Thus for thirty years he has carried on with marked ability and skillful technique fundamental researches.
>
> It is, therefore, a pleasure, on behalf of the Draper Committee, to present Dr. C. E. Kenneth Mees for the high honor of the Henry Draper Award.



DR. MARTIN KNUDSEN
UNIVERSITY OF COPENHAGEN.



DR. C. E. KENNETH MEES
EASTMAN KODAK COMPANY.

THE WATSON MEDAL AND THE PROMOTION OF ASTRONOMICAL RESEARCH

The James Craig Watson Medal and accompanying honorarium of $100 was

DR. ERNEST WILLIAM BROWN
YALE UNIVERSITY OBSERVATORY.

awarded to Dr Ernest William Brown, of Yale University Observatory, New Haven, Conn., "in recognition of his outstanding contributions to astronomical science, mainly in the field of gravitational theory in the solar system."

Dr. A. O. Leuschner, chairman of the board of trustees of the Watson fund, which recommended the award of the James Craig Watson Medal to Dr. Brown, remarked in his presentation speech that

> The problems of motion in the solar system have challenged the ingenuity of the greatest mathematicians and theoretical astronomers. Of those who have contributed to their solution none has attained the precision in representing the observed positions of the moon than Ernest W. Brown has achieved in his well-known theory. In 1907 he received the Gold Medal of the Royal Astronomical Society on the completion of the literal and numerical theory. At that time about a dozen lunar theories had been produced. Of these that of Hansen held its place in the nautical almanacs. Before Brown's theory could replace that of Hansen it was necessary for him to make his theory accessible in the form of tables. His tables have been uniformly used in the nautical almanacs since 1923 and predicted the 1923 eclipse with surprising accuracy. The honors which Brown has received were prompted not only by his lunar theory, although he had made it his principal task since 1890. At the same time his genius has conquered a variety of other hitherto unsolved problems based on Newton's Law of Gravitation. All these endeavors have led to new and significant results. The award of the Watson Medal therefore is based on his notable contributions to gravitational theory in general rather than on the specific achievement of the lunar theory.
>
> The academy may justly be proud to count him among its members and to be able to honor him by the bestowal of the Watson Medal.

THE MARY CLARK THOMPSON MEDAL

The Mary Clark Thompson Medal and accompanying honorarium of $250 was awarded to Dr. Amadeus Grabau, of the National University of Peking, Peking, China, "in recognition of his long and distinguished record in paleontology and stratigraphic geology." Dr. Waldemar Lindgren, chairman of the committee on the Thompson fund which recommended the award to Dr. Grabau, emphasized in his presentation speech

DR. AMADEUS GRABAU
NATIONAL UNIVERSITY OF PEKING.

the distinguished services of Professor Grabau in general and stratigraphic geology, in the science of non-metallic mineral deposits, and particularly in paleontology. His paleontological researches cover the Paleozoic of New York, and during the last seventeen years the paleontology of China The results of this work are contained in a splendid series of monographs on Chinese Paleozoic and also Mesozoic fossils, the last volume of which was published like the rest by the Academia Sinica, in Peking. His contributions are fundamental and exhaustive. And this in spite of severe physical handicaps during later years which would have discouraged any man with less courage and energy. Among his characteristics are an indomitable nature; a faculty of inspiring others with his enthusiasm; an ability to plan and carry out the work to which he has devoted his life.

In presenting this medal we are paying a just tribute to a most distinguished paleontologist and geologist who has brought honor to American geology to the four corners of the earth.

We regret deeply that Professor Grabau is unable to be here in person but rejoice that we may entrust the medal to Mrs. Grabau, who is here with us to-night and who will transmit the token to Professor Grabau with our admiring regards

In the absence, in China, of Dr. Grabau, the medal was received by Mrs. Mary Antin Grabau on behalf of her husband. In the acceptance speech, prepared by Dr. Grabau and read by his wife, Dr. Grabau gave a brief summary of the work with which he has been identified in China during the past seventeen years and of the remarkable progress that has been made in recent years in geological and other scientific work in China To quote from his speech:

The scientific study of natural history is now a recognized intellectual pursuit in China and those of us who were privileged to be present and in a measure give aid during the early years of development, feel confident that in the years to come geological, paleontological, biological and archeological contributions by Chinese naturalists will become of increasing importance, not only to their home country, but to the world of science at large.

Chinese naturalists feel as I do, that in honoring me to-night you are giving recognition to the progress of the scientific work in China, and they take it as an encouragement for the unabated continuance of their endeavors.

With this interpretation of your award to me of the Thompson Medal and with my sincere personal thanks, I accept the honor.

F. E. Wright,
Home Secretary

THE NEW BUILDING OF MELLON INSTITUTE

Mellon Institute of Industrial Research at Pittsburgh began a new phase of its career when its new building was dedicated in May as the principal event of a series which was attended by scientific and industrial leaders of this and other countries.

Dr. Edward R. Weidlein, director of Mellon Institute, presided at the formal dedication and addresses were given by Mr. Andrew W. Mellon and Mr. Richard K. Mellon, representing the founders. Other speakers were Dr. Irving Langmuir, Dr. Harold C. Urey and Dr. William P. Murphy, all of whom are Nobel laureates.

The new building is the third home of the institute, which started as a separate organization in a small frame building on the campus of the University of Pittsburgh twenty-six years ago. In 1915, the institute moved into its second home, the building recently vacated, in which it carried on the work which earned for it a national and international reputation.

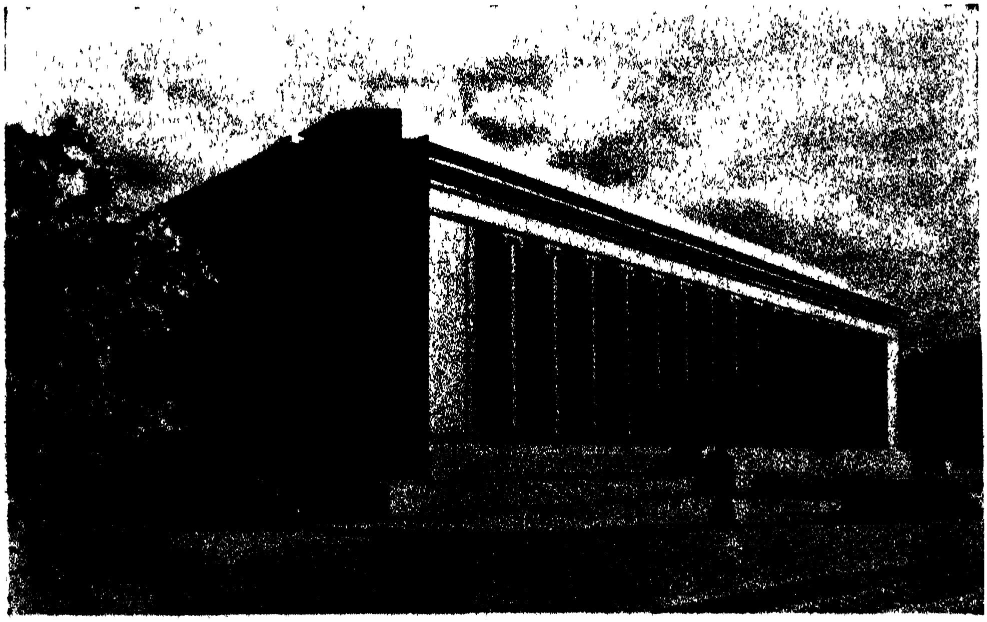
Long before floor plans were drawn for the present edifice two fundamental requirements were established by the founders. First, the building must be the most advanced scientific workshop that modern knowledge could provide. Second, it must be beautiful as a tribute to science and to the institute's own achievements. From the outset, preference was weighted heavily in favor of the Grecian school of architecture, which combines beauty with the simplicity appropriate to a home of science.

In form, the structure is built as a hollow square, wider at the front than at the rear and with center and connecting wings in the shape of a cross. This arrangement provides four interior courts which are the main natural light sources. The building is 306 feet wide at the front, 227 feet wide at the rear, and 334 feet from front to rear Institute requirements made necessary a structure of about six and one-half million cubic feet—four times the amount of space in the previous building.

Many features of the new edifice derive from some of the finest examples of ancient Grecian architecture. Its façades are very nearly the same in proportion as the long lateral façades of the Parthenon at Athens. Other details were inspired by the temple of Nike Apteros on the Acropolis and the temple of Artemis in Sardis, Asia Minor. To many visitors the most impressive features of the exterior architecture are the beautiful limestone, monolithic columns, of which there are 62 in the four façades. As they came from the quarry the rough blocks each weighed approximately 125 tons, the finished columns weighing about 60 tons. These columns constitute the largest monolithic column installation in the world.

The building has nine stories, three of which are built below ground level. The main or fourth floor is occupied by the executive offices, general office and library. The three lower floors contain the various general service departments and the sections for large-scale experimentation. The fifth to eighth floors, inclusive, are given over to laboratories, while the ninth floor houses much of the ventilating apparatus. The major portion of the building is now finished, but certain portions have been held in reserve to provide for the installation of special facilities and research groupings. The finished portion has a total of 355 rooms.

The first floor contains equipment for supplying compressed air, vacuum, hot water and refrigerated drinking water as well as service equipment, such as air-conditioning machinery for the auditorium, the main switchboard, motor generator sets and the main plugboard for special currents. On this floor and other lower floors a large amount of space is provided for unit plant installations in individual rooms and especially in the large engineering laboratories, which



NEW BUILDING OF THE MELLON INSTITUTE.

A CORNER OF THE MAIN LOBBY

THE ROOM IS CARRIED OUT IN SIMPLE GREEK ARCHITECTURE. WALLS, CEILING AND FLOOR ARE OF BOTTICINO MARBLE, EXCEPT FOR THE THIN, DARK STRIPS OF NEBO MARBLE WHICH ACCENT THE FLOOR. THE BAS-RELIEF OVER THE DOORWAY DEPICTS THE CREATION OF SCIENTIFIC KNOWLEDGE AND SYMBOLIZES THE WORK OF THE INSTITUTE.

occupy an L-shaped area two stories high. Here machinery and processes are developed and applied to translate laboratory methods into sub-commercial production.

On the second floor is the auditorium, which seats 350 persons and is completely equipped with motion pictures, stereopticon and amplifying equipment. Also located here are machine, woodworking, pipe, sheetmetal and electrical shops for service to all the fellowships, as well as a cold storage room, electric furnace room and the electrochemical laboratory.

Space for social and recreational activities has been provided on the third floor. Also on this floor are the building control room, the telephone switchboard, apparatus for the automatic telephone system, rooms for the storage of special instruments and apparatus, the photographic laboratories and other facilities. The library is the principal feature of the fourth floor. This beautiful room is finished entirely in Slavonian and English oak and has the style of the Renaissance, with influences from the works of Sir Christopher Wren and Grinling Gibbons and also from the Tirolese styles of the same period. It will accommodate a collection of 100,000 volumes.

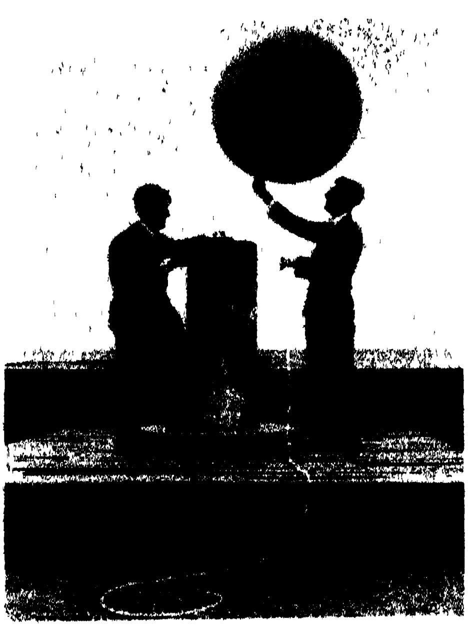
While each of the four upper laboratory floors has special rooms, most of the space is occupied by the two types of laboratories adopted as standard by the institute. The small laboratories are 12 feet by 19 feet in size and the large laboratories are 19 feet square. In design and equipment these laboratories represent the results of several years of experimental work by the institute's executive staff. In the laboratories and other parts of the building, many innovations were designed to meet the requirements of the institution, some of which are products of the institute.

J. D. U.

CHARTING THE NIGHT WIND

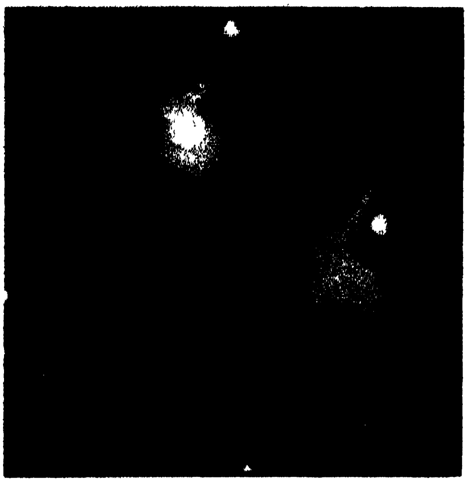
A PHOTOGRAPHIC method of charting the night winds high above the earth to determine direction and velocity for weather forecasting and aircraft operations has been worked out in the meteorological laboratory of the Massachusetts Institute of Technology by Athelstan F. Spilhaus, of the Woods Hole Oceanographic Institution.

The method makes use of a "whole sky camera," which has a 180-degree lens, a pilot balloon and magnesium flares attached at intervals to a length of ordinary blasting fuse. From an observation point on the earth the camera lens is pointed upward, and as the sounding balloon ascends the flashes of the magnesium flares, ignited at known intervals, are recorded on the plate. The photograph taken by the 180-degree camera is circular, the circumference depicting the horizon all around, and the brilliant magnesium flashes are registered on the plate regardless of the direction in which the balloon moves. Thus, by measuring the angles of elevation and direction between the camera station and the flashes, and correlating these data with the rate of ascent of the pilot balloon, an accurate record of the wind velocity and direction is obtained.



EQUIPMENT FOR STUDYING THE NIGHT WINDS

THE APPARATUS CONSISTS OF A SOUNDING BALLOON, A LENGTH OF FUSE, ALONG WHICH ARE ATTACHED MAGNESIUM FLARES, AND A 180-DEGREE CAMERA. THE LATTER IS MADE UP OF A LARGE LENS BARREL AND SHUTTER, AND A PLATEHOLDER.



A RECORD OF THE NIGHT WINDS

IN THIS PHOTOGRAPH THE CIRCUMFERENCE OF THE CIRCLE IS THE HORIZON WITH THE CITY LIGHTS SPOTTED ALONG ITS EDGE, WHILE THE ZENITH, DIRECTLY OVERHEAD, IS IN THE CENTER OF THE CIRCLE THE WHITE SPOT AT THE TOP IS TO MARK TRUE SOUTH AND BELOW IT ARE A SERIES OF 18 MAGNESIUM FLASHES INDICATING THE COURSE OF A PILOT BALLOON. BY MEASURING THE ANGLES BETWEEN THE CAMERA AND THE VARIOUS POSITIONS OF THE FLASHES, WIND DIRECTION AND VELOCITY ARE OBTAINED. THE FAINTEST FLASH WAS TAKEN AT A DISTANCE OF SEVEN MILES WHEN THE BALLOON HAD REACHED AN ALTITUDE OF 13,000 FEET. AT THE RIGHT IS THE MOON, WHICH WAS SHADOWED FOR PART OF THE EXPOSURE BY THE PHOTOGRAPHER.

The usual method of measuring winds of the upper atmosphere, which often blow in the opposite direction to the surface winds, is to release a hydrogen-filled pilot balloon and follow its course by means of a theodolite on which the angles of elevation and direction are read every half minute or minute. At night it has been the practice to suspend a paper lantern containing a candle from the balloon and to train a theodolite on the light. The disadvantages of this method, however, are that the light is extremely dim and is frequently lost in a short time. Observers have also been known to confuse the faint light of the lantern with stars The Spilhaus method makes it possible to take readings photographically at very brief intervals, and the apparatus may be used by inexperienced observers. All that is necessary is to open the shutter of the camera and release the sounding balloon after lighting the fuse to which the magnesium flares are re attached for any desired flash interval.

Tests of the new method have been carried on for several weeks through the cooperation of the new Dewey-Almy Chemical Company, which supplied a new type of sounding balloon. Test plates for recording the magnesium flashes at distances of as much as seven miles and at heights of over 13,000 feet have been made. It is expected that this distance and height can be greatly exceeded.

In the field of meteorological research the Spilhaus method of nocturnal soundings will provide a means of making detailed studies of the structure of the winds. The intervals of observation can be reduced to five seconds for such investigations, an interval far too brief for theodolite observations.

J. J. R.

THE TAKIN GROUP AT THE PHILADELPHIA ACADEMY

The habitat group of takin from Western China, opened in the Free Natural History Museum of the Academy of Natural Sciences of Philadelphia, is the first of its kind to be exhibited anywhere, and shows these rare and strange-looking animals in an unusually attractive setting, quite different from any of the other large groups in the museum. Flanked by huge blooming rhododendron bushes such as abound in the mountains of Sze-Chwan, where Brooke Dolan, II, secured the specimens on an academy expedition to that far region near the Tibetan bor-

THE HABITAT GROUP OF TAKIN.

der, four of these cattle-like mountain antelopes are shown near a stream, with mist-veiled rugged heights in the background.

First mentioned some 600 years ago by the famed Venetian traveler, Marco Polo, who described them only as "very wild, fierce animals," the takin remained a mystery until native Chinese hunters brought a specimen to L'Abbe David in 1869, since when occasional explorers have recorded it. Now, for the first time, it is shown as if alive in its almost inaccessible native haunts—a large bull, two cows and a calf grouped in life-like attitudes.

These curious beasts, with shaggy coats of mingled brown and buff color and short curved horns, live at altitudes of 7,000 to 16,000 feet, in the dense bamboo and rhododendron thickets. Though larger than the Rocky Mountain goat which is found in the Western United States, British Columbia and in Alaska, they probably are related to this animal. Despite their bulk, they can get over rough ground at an amazing rate, and this makes them difficult to approach. They possess great strength, and the natives regard them with considerable awe.

These awkward-looking, rather clumsily built animals travel in small herds, each of which follows an old bull as its acknowledged leader. To such a pitch is this blind obedience carried that one native hunter has reported that when he shot a leader, which then fell over a high cliff, the rest of the herd immediately leaped into the ravine.

This new group represents the latest development in museum exhibits of this nature All the artificial accessories, including the remarkably realistic rhododendron blossoms, were made in the academy's Department of Museum Exhibits, and the group was erected under the direction of Harold T Green, curator of that department. The background was painted by C. Clarke Rosenkranz, and the animals were mounted by Louis Jonas.

L. M. H.

THE SIZE OF ATOMIC NUCLEI

Of all the domains which the mind of man has to contemplate, the nucleus of the atom is the smallest. It is at least a thousandfold smaller than the sizes we usually ascribe to the atom itself and, indeed, if all the nuclei in the world were placed in contact with one another, their smallness is such that the earth could go inside an ordinary sized room. The study of the size, or more definitely the radius, of the nucleus of atoms has, however, been rather disappointing up to the present time. Various methods of estimating nuclear radii have been devised, none of which was extremely precise, but which showed that a general law governed the size of a nucleus, which can briefly be stated. This law is "the volume of a nucleus is proportional to the number of particles in it." In less colloquial terms the radius of a nucleus is proportional to the cube root of its atomic weight.

So simple a rule as this could have been guessed easily by any one and therein lies the disappointing nature of the study of the nuclear radius, for the conclusions we reach substantiate a law which needs only the most general ideas for a foundation. If, however, definite exceptions to this simple rule could be found, we should have a chance to use these exceptions to tell us more intimate facts about the nature of the nucleus. Recently such an exception has been found. In work at Yale by the writer, H. L. Schultz and Gordon Brubaker, the transmutation of argon into calcium has been observed and studied with striking results. A helium nucleus, or alpha particle, is fired into an argon nucleus and is caught by it to form an unstable conglomerate which breaks up into calcium and a neutron, which last can be detected by the apparatus. The interest lies in how the reaction proceeds as the energy of the incoming alpha particles is changed. A nucleus acts in many ways like a volcano and crater as far as its behavior to incident nuclei is concerned—that is, it repels them until a certain distance is reached and then attracts. In terms of the volcano the crater can not be reached until enough energy has been spent to reach the top and then it is all too easy to fall inside. By studying the energy at which the transmutation takes place readily the height of the volcano (or potential barrier) and the radius of the crater (or nuclear radius) can be found. For argon it is found that the nuclear radius is nearly 30 per cent. larger than expected, so that its volume is double the normal value. This means that argon does not fit into the accepted scheme, and thus revives hope that the study of nuclear radii may help us to gain information about the inside structure of the nucleus. This is, the writer considers, the most important result achieved.

Some further results have been obtained which lend themselves to speculation. At the same time as the argon reaction was discovered a similar transmutation of chlorine into potassium was achieved and a study of the volcano and crater made. A much smaller radius was found, though not quite as small as would be expected, so that again an interesting anomaly is found. Now the resulting potassium is of a radioactive form which has been known for some time. Its radioactivity has been difficult to explain, for the radioactive process took place with a considerable energy liberation and would normally have proceeded very rapidly. Actually it proceeds extremely slowly. Why? One possible explanation is that the potassium nucleus has a rapid rate of rotation which has to be changed in its radioactive process. This change is so great that it slows down the radioactivity enormously and gives radiopotassium its unusually long life. It seems to the writer that if we assume that chlorine, too, has a rather large radius (close to that of argon, which is its neighboring element) but that the helium projectiles have to supply additional energy to create the rapidly spinning potassium nucleus, then the apparently smaller radius for chlorine can be explained and also the long lifetime of potassium. While calculations seem to bear out the truth of these ideas, this suggestion must still be considered as speculation. As time passes and more exact experimenting is completed, the idea can be checked.

ERNEST POLLARD

YALE UNIVERSITY

THE SCIENTIFIC MONTHL

AUGUST, 1937

LIBRAR

CONTRIBUTIONS OF THE MELLON INSTITUTE TO THE ADVANCEMENT OF SCIENCE[1]

A NATIONAL ASSET

By Dr. KARL T. COMPTON

PRESIDENT, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

It is a natural law, supported by both logic and experience, that it is the useful which survives. It is to their fundamental social value that such institutions as family, church, university, business and government have existed from time immemorial, each supplying an essential ingredient of that complex compound of mankind in the aggregate that we call society. Though changing in form to meet changing conditions and styles of living, these institutions continue to perform the essential functions respectively of reproduction, spiritual satisfaction, education, distribution and regulation.

It is important to note the ever-changing form and performance of these institutions, even though their basic function remains unaltered. The family in the days of Abraham, Isaac and Jacob was differently organized and faced different problems than the typical Pittsburgh family of 1937. Governmental authority has been variously vested—through personal physical prowess or conquest or heredity or purchase or demagogic persuasion or election by the people. Business has developed from the days of barter and hand labor to the present era of monetary transactions, mass production and high pressure distribution. Universities have changed vastly in their curricula and methods of instruction, but they are still devoted to the three original objectives: disciplined intellect, professional skill and new knowledge.

Our attention on this auspicious occasion is naturally directed toward two of these basic institutions, the university and business, since the Mellon Institute is derived from both and serves the public through both. I suppose that it would be proper to designate the Mellon family as the father of this institute, its parenthood made possible by success in business. Likewise the institute's mother is the University of Pittsburgh, within which it has developed and been reared to take its prominent place as an active member of that important group of institutions which perform essential national service in education and research.

A number of influences converge at the present time to enhance the value of the Mellon Institute and other institutions which perform similar functions, and of these influences I would speak briefly as follows.

In the first place, the Mellon Institute is a scientific institution, and science is at the very root of our national program of objectives which our President has phrased as "the more abundant life." True, we do not see science advertised as an objective in political party platforms or even in the President's own messages to the Congress or to his friends, the people. It is even likely that few of those who are urging the various measures for improving the social and physical aspects of the nation have any real understanding of the fundamental rôle that science must play if these measures are to be successful. Yet this rôle exists, as the following analysis shows.

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[1] Based upon addresses presented at the time of the dedication of the new building of the Mellon Institute of Industrial Research in May.

Prominent among our avowed national objectives are: the banishment of disease; elimination of unemployment; higher standard of living, including higher wages, shorter hours and greater opportunities for comfort and recreation; abolition of child labor; educational opportunities for all; social security against economic hazards or distress in old age; protection against natural hazards of flood, drought, wind, fire and earthquake; new markets for agricultural products.

I make bold to assert, for I believe that it can easily be proved, that there is not one of these fine objectives but that is basically dependent on science for its achievement. Take, for example, higher wages and shorter hours. Real wages are composed, of course, of all the things which a worker gets in return for his labor. In the last analysis the total wages which can be paid consist simply in the total number of necessary and desirable things which are produced in the world. Every new and useful product developed by science adds just so much to the sum total of real wages, and every machine for increasing production makes possible either more wages or shorter hours of labor or both.

It is a pity that so many of our social and political reformers have not evolved much beyond the "cave man" stage in their thinking. From the days of the cave man, all through history up to the modern era of science, there were only two primitive recipes for achieving the "more abundant life." One was to work hard and long in order to produce more; the other was to take the good things of life from some one else—by conquest or theft or taxation or exploitation. Too much of the doctrine of the more abundant life, even in our day, is based on the latter one of these primitive philosophies. To work hard and long to improve our lot has gone out of style; now the slogan is to soak the rich and to demand more while giving less.

Over against such primitive, though still popular, methods of seeking the good things of life, there is the sharp contrast of the modern method of putting science to work for us. If, by a practical application of science, men are enabled to produce with tenfold rapidity, it is evident that they can get along on their former standard of requirements, by working only one tenth as long as they had previously done. Or, if they want to work half as much as they did before, they will still produce five times as much as before, so that the average man's real wage will consist of the products of five times as much labor as he used to enjoy.

This is the basic philosophy of science as a means toward social betterment. Science creates new materials, new methods and new opportunities. There is real danger that, in the present activity of labor to demand more wages and of government to demand more taxes to support its altruistic aims, the demands may exceed the supply. In other words, demands for wages and taxes may exceed the capacity of industry and agriculture to produce. The only hope in such a situation is for science still further to add to man's ability to produce desirable things. In fact, had it not been for the past achievements of science, our wages and standards of living would still be, for the masses of the people, at the primitive levels of constant struggle against starvation and suffering.

Let me give a very up-to-date example of the social values of science. It is an old story, of course, that the automobile industry has provided enormous employment at about the highest wages of any large industry in history, and that the automobile has opened up new opportunities of living, recreation and achievement to millions of people. Here, however, is a more recent aspect. The number of automobiles sold in the past year in America was approximately equal to the number sold in the last boom year of 1929. By all measures, the new car is at least 50 per cent. better than that of 1929—in economy of operation, safety, comfort and general quality. Yet I am informed that the aggregate cost to the public of the present cars was $700,000,000 less than in 1929 So Mr. Citizen has a much better car and has saved $700,000,000, which he can spend for something else that he wants, such as a better home, more delicious food, travel, books, life insurance, clothes or a thousand and one things which altogether signify the "more abundant life."

The state of civilization of a people has been defined by the degree to which they are willing to sacrifice present pleasures for the sake of future benefits. If we all were really highly civilized and intelligent, we would see some striking contrasts to our present situation. We would see labor unions demanding the introduction by all industries of labor-saving and rapid production machinery in order that they might achieve higher wages and shorter hours. We would see the political forces of the country even more insistent in demanding the creation of new wealth than its distribution. In times of economic stress we would see the government strengthening its scientific services instead of curtailing them most severely of all services. We would see the agricultural problem tackled by a powerful scientific attempt to discover new uses for agricultural products rather than trying to achieve prosperity by curtailing production. We might even see income taxes which would encourage, rather than suppress, the man who creates a great and useful industry and who uses his wealth in a far-sighted manner for the public good.

Unfortunately our state of civilization, as a group, still falls far short of any such Utopia of intelligence. But fortunately there are some individuals who have vision, understanding and altruistic spirit who have also the ability and initiative of leadership, and who therefore supply those essential elements of progress which are lacking in the body politic. It is to such men that the world has always owed its slow but steady rise from barbarism to its present state of semi-civilization and improved standards of living. It is to such men that the world owes this Mellon Institute, which has already contributed so notably to our national welfare and which is to-night signalizing a new era of even greater accomplishment.

Since we all understand in a general way the functions of the Mellon Institute, and since there are many here more competent than I to discuss its operations in detail, I will confine my comments simply to a statement of its basic significance.

I have already spoken at length of the basic rôle of science in any program for social progress. Science's rôle extends all the way from the first observations of the facts of nature, through experiment and theory and still more experiment, past the formulation of proven principles, on through the practical applications of these forces and materials of nature for the benefit of mankind. These operations of science on a significant scale are fostered primarily by two of the institutions whose stable and essential character I remarked in the beginning—the universities and business. For it is in the universities, to a far greater extent than anywhere else, that the basic facts of science are discovered and studied, and it is there that the scientists themselves are trained. And it is business enterprise which organizes for the efficient production of the materials produced by science or which uses these materials for the performance of such essential functions as transportation, communication and other public services Many progressive business organizations have built up great scientific organizations of their own, to conduct research and development of their own products

The Mellon Institute fits strategically into this scheme, midway between the university and industry. In it the scientific discoveries made in the universities may be examined and developed with reference to their possible industrial value; in it the technical troubles of industry may be cured and its ambitions for new and better products or methods satisfied by the aid of science It serves also as a training ground and recruiting center for applied scientists who will later be absorbed into industrial organizations. It provides the facilities of a research laboratory to the thousands of industrial units which have not as yet been able to justify the establishment of research laboratories of their own. In many cases, it demonstrates to an industry the advantage of creating its own permanent laboratory, as, for example, in the case of the now great research organization of the Gulf Oil Company, which originated in a research project at the Mellon Institute.

In the light of all these facts, facts of experience and facts of the present situation, and in a time when a crying need of the country is for the development of new industries, new uses for farm products, new forms of wealth that people will work and pay to possess, I can think of no better designation of this great institute, in which university and business unite to serve the nation through science, than to say that it is a "national asset." The Mellon Institute is performing a function which the government is not and probably should not be performing. But this function is so important that this institute and all other institutions which are similarly contributing to improve the general standard of living in basic ways through science should be encouraged and aided in every possible way by favorable legislation and private philanthropy.

As a representative of a sister institution which follows the same ideals, I offer congratulations and best wishes to the University of Pittsburgh and to its Mellon Institute at this celebration of its increased effectiveness, and I would express to the Mellon family my sincere conviction that their generosity has been well conceived in the public interest.

RECENT PROGRESS IN SYNTHETIC ORGANIC CHEMISTRY

By Dr. G. O. CURME, JR.
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I HAVE always thought of the Mellon Institute as one of the spots in the world where new scientific discoveries are most sought for and best appreciated. Accordingly, it seems quite appropriate that this discussion of recent progress in science should be held here, where the accomplishments of scientists from all countries are constantly under review. I doubt if I can add any wholly new scientific facts of particular moment to the store already available. Valuable discoveries, when they become definitely established as representing progress, are always well known. The really new ideas that will be acclaimed in years to come are now being worked upon by those who have faith in them but are obscured by the great mass of accumulated scientific knowledge. I hope, however, that a review of the significant accomplishments in that robust field of chemistry and industry, synthetic organic chemistry, may lead to a clearer understanding of its potentialities and thus enable still further progress to be made.

I have had for many years a deep personal interest in the general field of research which is represented on our program to-day by Dr. Banting. His activities and those of his colleagues are far removed from those with which I have been directly concerned, but I am sure that all scientists have a keen appreciation of the brilliant research and significant results which have come from the investigations on glandular extracts and vitamins. I have also taken some professional pride in the fact that these marvelous regulators of body functions, when isolated, have been found to be pure organic chemical substances and that an increasing number of them have been synthesized by purely chemical methods. As this joint field of medicine and chemistry has developed, there has occurred to me the similarity between the behavior of these synthesizable organic chemicals in regulating the animal economy and the behavior of the synthetic organic chemicals of industry in regulating many phases of our industrial economy. This comparison, of course, is somewhat fanciful and like all similes can not be carried too far. It is true, however, that synthetic organic chemicals have found and are finding valuable uses in almost all types of industrial operations and in general, although consumed in relatively small quantities, produce an effect out of proportion to the quantities involved.

A study of synthetic organic chemistry from this standpoint is somewhat at variance with the concepts of scientific research as established in earlier days in our universities. At one time generally and in many instances still there has been the thought that with millions of possible chemical compounds yet to be synthesized and described, the obvious duty of an organic chemist is to make and describe more and yet more new compounds. This is still a laudable purpose, and science should not be satisfied until all possible forms of matter have been catalogued and described. Concurrent with this effort, however, there is an obvious need for other scientific research which shall investigate the interaction of known compounds with other materials, so as to find out what unpredictable properties or potentialities may exist in new combinations. In biochemical and medical research a principal effort is made to study the effects of a particular substance or combination of substances on the human body and from such investigations the remarkable biochemical accomplishments of recent years have come. In my opinion, the greatest recent progress in synthetic organic chemistry also has come from a study of the application of previously known materials to practical uses along the general lines laid down by Dr. Duncan and since developed to a high degree at the Mellon Institute.

As is invariably the case when an effort is made to establish a definite beginning of a particular movement, it is found that there is always a prior event that deserves consideration. Certain syntheses of organic products certainly were made long before Wöhler's classic synthesis of urea, such as those of ethylene dichloride and of mercury fulminate. However, I am quite content to consider Sir William Perkin as the first scientist to conduct an organic synthesis purposefully and apply it in an intentionally useful manner on an industrial scale. Establishing such a date is of importance only in showing that all synthetic organic chemistry has been developed within the last eighty years and thus deserves to be considered fairly recent. The development of organic materials of predetermined characteristics to fill definite needs in industry is much more recent and has been employed on a wide scale only in recent years.

Whenever a new field of activity is opened up, new developments starting from a focal point expand in all directions on an ever-increasing front. Furthermore, as the sum of accomplishment becomes greater, the relative increase resulting from any one discovery becomes smaller. In my opinion the time has passed in the synthetic organic chemical field when a revolutionary discovery, such as Schönbein's nitrocellulose or Perkin's mauvein, can be expected that will dwarf all preceding discoveries by comparison. This is not because many major discoveries are not at this time in the making, but rather because the progress already made is too substantial. The spectacular days of pioneering in a wholly new field are passing, but the important task of applying the valuable contributions of synthetic chemistry to our industrial and economic problems is just getting under way.

Since the time of Perkin, these materials, which on superficial inspection seem most unimpressive, have set up some rather striking records of performance in open competition with all other available materials. It has been shown that organic chemicals other than those which are physiologically active have the property of manifesting themselves in high dilution. As examples of somewhat unusual laboratory tests, I might mention the dyestuff, fluorescein, which gives distinct visual evidence of its presence when diluted with 40 million parts of water. Also the chemical, phenyl isocyanide, is recognizable by its odor in a greater dilution than that in which sodium is recognized by the sensitive spectroscopic flame test. These facts might well be classified as merely "stunts," interesting only to other organic chemists, and the inquiry made as to what could be done outside the laboratory. So, in the steel industry, which is far from the organic chemical laboratory, the acetylene flame cuts or joins metal shapes with enormously greater speed than any other means, and by the use of quantities insignificant compared with the tonnage of steel. In other cases where it is desired to strike the hardest possible blow, as in mining operations or in demolition work, the gaseous decomposition products from the detonation of synthetic organic chemicals, such as glycerol trinitrate or trinitro toluol, are employed. This has long been standard practice, and while taken as a matter of course to-day, it is still rather surprising to think that a pile driver, a stream of water from a nozzle and a gallon of nitroglycerine are capable of delivering an effective blow in the order mentioned. These performances, while more striking to the general public and constituting evidence that synthetic organic chemicals are not mere laboratory toys, were developed originally fairly early in the history of organic synthesis and are not fully representative of the ability of small quantities of a key material to motivate a whole industry.

A better example of this constituted a major field of research at the Mellon Institute twenty years ago in its investigation of frothing and collecting agents in the flotation process of concentrating ores. This type of operation, which has since found large-scale success, consumes a most minute amount of organic material, frequently of synthetic origin, but by its spectacular performance permits mining operations to be conducted profitably that otherwise could not be supported, and affects all the metal-consuming industries of the country in lowering costs and expanding ore reserves. Another similar case is the field of photography, never considered an organic chemical operation by most people. Yet without the sensitizers, developers and the plastic film, modern photography could not exist. The motion picture industry occupies a prominent position in our modern life and gives profitable employment to large numbers of people as well as education and enjoyment to still larger numbers. As such, it is an excellent example of a modicum of synthetic organic chemicals, animating a large human activity, which makes the active principle involved seem insignificant by comparison. These illustrations are not overdrawn cases, prepared for the purpose of glorifying the organic chemist. They are characteristic of the applications of these relatively new chemical products, where the original research on the material has been followed by even greater effort in studying its application.

In the short time at my disposal I can not go into an enumeration of the many parallel industries which have been either created *in toto* or brought to a wholly new degree of effectiveness by the studied interweaving of synthetic organic chemicals with other products and forces to produce an economically important result. National defense against human aggressors as well as sanitary defense against microorganisms in their modern form depend largely on synthetic organic chemicals as key products. The modern automobile and airplane, the outstanding accomplishments of the twentieth century to date, would be far from their present standard of excellence without the regulating effect of the synthetic products used in their construction and operation. Anti-knock fuels, special lubricants, durable tires and other rubber goods, anti-freeze materials, lacquer coatings, safety glass, brake fluids, plastic products, among other features, have permitted the remarkable degree of perfection and low cost which these unique products of our generation have attained.

It has been observed that those industries which are judged progressive by accepted standards are large consumers of synthetic organic chemicals and that those similarly judged as backward are among those whose consumption of these products is restricted. Such a statement is, of course, only relative, but it is most assuredly true that modern technology counts heavily on the tools supplied by synthetic organic chemistry and that the older technology, created before synthetic products became available, is rapidly being superseded. With the shining example of the more successful industries being heralded throughout the industrial world, the possibilities of modern technology are being adopted as rapidly as conditions will permit by other industries which have been less successful in their competition for the customer's dollar. Although such a movement is not particularly spectacular and must require a long time for completion, it seems to me one of the most important trends of the present time.

Our home construction industry has received much criticism during recent years, and on the basis of value received for cost and effort, it must be conceded that this criticism is largely deserved. That such a subject has reached the stage of public discussion, however, indicates that improvement has already begun. Our homes may not seem to us a chemical project, but in the countless applications of plastic materials, lacquers and synthetic fibers we may confidently expect new types of assembly to emerge with greatly reduced costs, while giving sanitary, noiseless, fireproof, moistureproof and verminproof construction, in keeping with known possibilities.

These plastics, in their scientific and technical development, as well as in their application to home construction and other industrial uses, constitute one of the major fronts on which synthetic organic chemistry is advancing to-day. In conception they are as old as the pitch and sun-dried bricks with which Noah and his predecessors were familiar. In their scientific understanding they are so new that not one of our universities offers an adequate course of study, preparing students either for engineering application or research on plastic materials. Such scientific study as these materials are receiving is being carried out in the research laboratories of a few industrial concerns, and the excellent results now being obtained are a tribute to the possibilities inherent in this class of materials. Many industries other than construction are benefiting by the use of plastics. Decorations and trimmings of plastics are very common to-day. Pack-aging of foodstuffs has benefited from this use, as in the case of canned beer, which was made possible by a thin coating of a moisture-proof plastic material inside of the tin coating. Sound reproduction records, electrical insulation, parts for telephone and radio receivers and transmitters are among the growing list of uses for these materials. Extensible plastics or "synthetic rubbers" are also included in the list, which are rapidly leaving the experimental stage and becoming practical realities

The rapid growth of cellulose acetate rayon has brought the stimulus of new possibilities to the textile industry, which welcomed synthetic dyestuffs eighty years ago. Other spinnable materials are now being experimented with which promise wholly new properties in textiles. New lubricants, sizing and other textile chemicals are under investigation, all of which should eventually assist in permitting improved textile products at lower costs. Among these textile chemicals, new synthetic materials lending special properties to aqueous solutions are of importance. Detergents and wetting agents which excel in certain respects the performance of soaps have been developed and put on the market recently. These are still in an experimental stage, and their eventual field of major usefulness remains to be determined. However, they serve at present to show the reawakening of interest in modern technology by the textile industry.

It has long been popular to lament the backwardness of our rail transportation units. The growing fleets of streamlined trains provide an appropriate reply that this important service industry is already undergoing a revision to increase its effectiveness. Since the Diesel motor unit is in reality of greater significance than the more obvious streamlined exterior, there is reason to expect that modernization of rail transportation will follow generally the trends of automotive engineering. In such event there is a certainty that synthetic organic chemicals will serve their part well, although the general public may notice them only indirectly, through the passing of former inconveniences.

Agriculture has always been most conservative and as an industry based on photosynthesis of organic products has, in a sense, been competitive with industrial organic synthesis. Perhaps a compensating benefit of the trying times of the past several years has been the arousing of mutual interest between these two groups For some years the farmer has been a buyer of special synthetic organic chemicals for farm use in the form of insecticides, seed disinfectants, fumigants, sterilizing solutions, weed killers and the like in addition to those purchased indirectly through household and automotive products. In return the chemical manufacturers have been large purchasers of agricultural products such as cotton, animal and vegetable oils, naval stores, starch and sugar, in addition to food and other farm products consumed by chemical workers. It is rather common to find in the chemical industry that among one's largest customers are other chemical manufacturers. Once it is generally realized that the agriculturist is essentially a producer of volume goods and the synthetic organic chemical manufacturer essentially a producer of specialties, tailored to meet rigid specifications, the few cases where competition exists should be overshadowed by the many cases where a mutually profitable exchange of goods can occur. Much public discussion of this subject has taken place recently and beneficial results should follow. It would be an exception to the past successes of the chemical industry, however, if the degradation of foodstuffs to a motor fuel, requiring a subsidy from our already overburdened taxpayers to offset the economic loss involved, were the best form of cooperation between chemists and farmers to be found.

This has been called an age of specialization and it has even been threatened that as our specialists learn more and more about less and less they will eventually approach the condition of knowing absolutely everything about nothing at all. If such a minute subdivision of our technical knowledge, or anything remotely resembling it, were ever to come about as a real condition, it would indeed be a serious situation. However, I firmly believe that there is less serious danger of dangerous excesses being indulged in by our scientific and technical specialists than by any other social group. The tendency toward ultra-specialization undoubtedly does exist to-day, but along with it other coordinating tendencies also exist. These offset the potential harm which might come from uncoordinated knowledge, while permitting the advantages which come from detailed study of individual fields. Among these coordinating tendencies, I consider that the interweaving of synthetic organic chemistry into almost all fields of experimental science is an important one. I have no false illusions about synthetic organic chemistry being the dominant science, for no science can be more than a relatively small part of our whole body of scientific knowledge. I do believe, however, that when synthetic organic chemistry is studied in its applications as well as in its origins of materials, it is peculiarly well adapted to bind together and harmonize the other branches of science and industry into a more effective and practical whole.

THE PROBLEM OF CHEMO-THERAPY IN PNEUMONIA

By Dr. W. W. G. MACLACHLAN

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In 1911 Morganroth, in Germany, noted that the quinine derivative, ethylhydrocupreine or optochin, had strong power to destroy the pneumococcus. Naturally, clinical investigations were made with this chemical in order to demonstrate its possible value in the treatment of the human disease caused by the pneumococcus (pneumonia). However, it was soon evident that this preparation had a most serious defect; namely, it produced blindness if given in a dosage adequate to be effective in human pneumonia. Smaller doses could be given with comparative safety as far as blindness was concerned, but the anti-pneumococcic power was consequently so diminished as to make the drug of little value in the severe or potentially fatal cases of this infection. The blindness was usually not permanent and was not present in all individuals, even if they took equal amounts of the chemical; but the loss of vision, if only temporary, was still a very serious complication and it made the use of ethylhydrocupreine in clinical medicine practically impossible. In 1930 Miura and co-workers, in Japan, brought out ethylapocupreine. They stated that it was more powerful and less toxic than ethylhydrocupreine. Gundel and Seitz, in Germany, and our group in Pittsburgh at the Mellon Institute in 1933–34 confirmed the studies of the Japanese workers. Unfortunately, this chemical, like optochin, also produced blindness and therefore could not be placed among the useful drugs of medicine.

For several years Dr. L. H. Cretcher, of the Mellon Institute, and I had discussed the possibility of chemotherapy in pneumonia, and sometime during the winter of 1930 we decided that the attempt should be made to produce a quinine salt which had power to destroy or inhibit the growth of the pneumococcus while at the same time to be free from the damaging effects on the vision of the patient.

The number of chemical preparations that have now been studied is 76. After each quinine derivative had been prepared by the chemists it was then tested by us in the following way; the effect on the growth of pneumococci in the test-tube was established; the ability of the chemical to protect white mice from death after they had been injected intraperitoneally with virulent pneumococci and an accurate quantitative measurement of the toxic dose for white mice of known weight was estimated. It was found that some preparations had considerable bactericidal power but were very toxic and were accordingly discarded. The opposite was also true, as a very slight toxicity was of no advantage if the preparation had lost its anti-pneumococcic power. In all the protection and toxicity experiments optochin and ethylapocupreine were used as controls, and the minimum unit of mice for each dose was 30, hence it is not surprising that the number of white mice used in this study is now about 20,000. The toxicity experiments in mice, however, do not give one any information regarding the most important factor that is seen in man when taking optochin, ethylapocupreine or occasionally even quinine itself, namely, visual disturbance. The rabbit appears to be immune to these eye lesions, and therefore, another species of animal had to be found for experimental study. In association with Professor W. T. Dawson we were able to get most valuable and essential information in regard to blindness by the use of a small number of dogs. This animal reacts in the same way as does the human as far as the eye is concerned. This experimental work was carried out by Dawson in the department of pharmacology at the University of Texas, and the subsequent microscopic examination of the eyes was done here. The eye lesion produced by certain quinine derivatives in the dog is pathologically a degeneration of the inner ganglionic layer of cells of the retina, and it is reasonable to assume that in man the same process occurs. This finding in dogs has long been known, and we have only confirmed the observation. But more important, we believe, is the fact that this experimental method can be wisely utilized to recognize in an unknown quinine derivative the presence or absence of the blinding factor, and hence save the human from such complications. Naturally these experiments in protection and toxicity consume time, and frequently the results are confusing, so that the words of Burns, "the best laid schemes o' mice an' men gang aft a-gley," seemed to us to be particularly appropriate at times during the past four or five years.

It was Dr. Cretcher's idea at the beginning of this research to attach to the complex molecule of quinine the hydroxy radicle, as it was known that at times this chemical arrangement reduced the toxicity and did not greatly interfere with the bactericidal or antiseptic power of the substance. Ethylhydrocupreine (optochin) and ethylapocupreine were both known to have strong bactericidal power for the pneumococcus, the latter being the more potent. The hydroxy radicle was fairly readily added to optochin, producing hydroxyethylhydrocupreine, known to us as No. 7. It was much less toxic than optochin, but its anti-pneumococcic power was also considerably lessened. This preparation was never used other than in experimental work. However, the chemical development of the hydroxyethylapocupreine was much more difficult. After about one year we were able to get a sufficient amount to test in animals and found that it had little toxicity and considerable bactericidal power, although less than ethylapocupreine. Hydroxyethylapocupreine for this reason was of great interest, and particularly so, when we found that it had no blinding factor for dogs. It was not until the winter of 1935–36 that we were able to get sufficient quantities of it to use in clinical pneumonia, and it was soon recognized that this chemical did not produce visual disturbances in the human. During the first year (1935–36) the amount of the chemical was very limited because at that time there was only about 5 per cent. yield. Fortunately, a new process was found during the summer of 1936 by Dr. Butler which raised the yield to about 40 per cent. Hence, during the winter of 1936–37 we have had an adequate amount for our clinical work.

We have seen during the past two years, in treating about 200 cases, not the slightest evidence of blindness. Furthermore, the dosage has been very large in many cases, from 400 to 800 grains or even higher during a week's time. The usual daily dose, for adults, is 120 grains a day, and it can be kept up for several days. It is given like quinine in capsules by mouth. It possibly can be given effectively by bowel, but we have had as yet little experience with this method, which may be very useful in the future for those cases that develop nausea. It can not be injected into the muscle, as it causes necrosis with subsequent abscess formation, at least if given in large doses, as is necessary in pneumonia cases. This winter we have given by vein the hydroxyethylapocupreine to a number of the very sick cases. In only one instance are we certain that a reaction associated with a blood pressure fall resulted. Locally, however, we expected and have seen a good deal of thrombosis of the veins at the point which receives the injection. The substitution of the acid salt, the dihydrochloride which we have used, by the neutral salt, the monohydrochloride, might lessen to a considerable degree the incidence of thrombosis in the veins. This problem is now being investigated. On only two occasions have we noted slight ringing in the ears, so commonly associated with even moderate dosage of quinine. This year nausea has been one of the frequent clinical symptoms associated with severe influenza. It was not noted in the previous year, and we, therefore, believe that its occurrence is not due to the chemical, although it may be intensified by its use.

As to our results for the past two years, we can say that the hydroxyethylapocupreine appears to be effective in a considerable number of cases. Unfortunately, during the past winter many of our pneumonias have had mixed infections. The *streptococcus haemolyticus* and the *Bacillus influenza* have been isolated from the sputum, blood and lungs many more times than in the previous years. The pneumococcus is present in practically all cases in addition. The hydroxyethylapocupreine has no bactericidal action as far as we know on influenza or on streptococcus infection. We treated in the first year about 50 cases and more than double that number during the past year. Very few cases were treated after the fourth day of the disease, for one can expect very little to be accomplished in late cases, as is also true for the specific type 1 serum. The majority were treated in the first three days. In going over our figures for the past two years, just two weeks ago, we were surprised to note that our mortality was very much lower in cases of pneumonia when treatment by the chemical began on the third day, than on either the first or the second day. This observation was the same for each year and the number of cases seemed to be large enough to strongly suggest something more than chance or statistical error. This finding one can very easily control next year. There may well be a reason for this difference in the mortality on the third day and if this proves to be correct in a larger series of cases the observation will have great practical importance as the mortality on the third day was only 4.7 per cent., while on the first day it was 26 per cent. and on the second day 34 per cent. This year for 100 cases treated we have had a 27 per cent. mortality; our normal mortality for 100 non-specifically treated cases in hospital work in Pittsburgh is about 45 per cent. There has been a definite difference in the mortality in the positive blood culture cases during the past two years. In 47 positive blood culture cases that were treated, 19 recovered, whereas, in 26 cases that were not treated, usually because they were late in the disease and therefore not true control cases, only 4 recovered. We are of the opinion that the mixed infection this year has increased the mortality and that likely in non-influenzal epidemic years it would be lower. As the mortality in pneumonia varies from 20 to 45 per cent. in different communities, it is important in comparing the results of treatment to note the relative change in mortality. In other words a 50 per cent. reducing in our mortality would still leave us with a figure as high as that reported for many other cities in the country. A proved reduction in mortality, however, in any given community should be applicable to all places.

At the end of two years' clinical trial we are impressed by the possibilities of hydroxyethylapocupreine. Clinical observations take time, and it will probably be several years before the exact place of this chemical in the treatment of pneumonia can be estimated. Naturally, our results must be confirmed by others.

An interesting observation associated with pneumonia has been the treatment of empyema, one of the common complications of severe infections. The pus in the pleural sac is aspirated and, depending upon the amount removed, a 1 or 2 per cent solution of hydroxyethylapocupreine is injected into the pleural cavity. Never more than 100 cc have been injected. The aspiration of the pus from the pleural cavity and the injection of the chemical is repeated several times, depending entirely on the clinical picture of the patient. We have not had any case this year requiring more than four injections. There will be, undoubtedly, an occasional case of empyema where the pus can not be reached by the needle and where drainage tubes will have to be inserted. The 1 or 2 per cent. solution of the chemical can then be used through the drainage tubes in the same way as Dakin's solution is now employed. Empyema carries a low mortality, but with the usual past methods of treatment it has been a slow process before the patient is cured. The injection method appears to shorten considerably the time of illness, and to lessen the discomfort of the patient by avoiding the excision of a piece of rib or the introduction of drainage tubes into the pleural sac. Optochin has been used occasionally in the past in the treatment of empyema by others and by us. We have also used ethylapoquinine, but in the past two years have substituted hydroxyethylapocupreine, as it is quite safe and in the stronger solution quite as effective. We have not had many empyema cases during the years 1935–37, about 12, but the results have been uniformly good. This, of course, does not apply to empyema produced by the streptococcus, as on this organism the quinine derivative has little or no action.

In conclusion, we can safely say that in hydroxyethylapocupreine we have developed a quinine derivative which is devoid of any visual disturbance and which appears to have power in affecting a certain number of pneumonia cases in man. Its exact clinical status will have to wait until a larger number of cases have been studied by others and by us. That opportunity, we hope, will be forthcoming to a considerable degree in the near future, when a larger supply of the chemical will be generally available. This chemical is compatible as far as we know with the use of any form of serum which may be given in certain types of pneumonia, and further the ease of administration will make it very available for the general practitioner of medicine to use early in pneumococcic disease of the lung.

QUALITY IN HUMAN POPULATIONS

By Dr. H. L. SHAPIRO

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STUDENTS of population, having amassed vast quantities of data, now find themselves a little embarrassed by their riches. Having refined their statistical methods to a degree of accuracy permitting them to venture into prophecy, they have become uncertain as to what their predictions bode for the welfare of man. Being able to plot the differential growth of various categories within the population, they are faced with the necessity of justifying their labors by determining whether the threatened quantitative changes have any significant qualitative correlates. It is obvious that if one class of the population is increasing more rapidly than another, this fact, however interesting, has no fundamental significance for the essential quality of the population if the classes are differentiated by merely ephemeral distinctions. The problem facing population experts, therefore, centers around the effort to discover what qualitative judgments can be safely made concerning the various categories with which they can deal, and to what extent these qualities rise from genetic origins.

This problem of quality has many aspects, but the one considered here is concerned with the methods employed by physical anthropologists of determining physical quality. It is not easy to summon from the clouds of vague verbiage which cluster around the concept of physical quality any significant contribution to its understanding made by physical anthropology or more strictly anthropometry. But on the reassurance that a critical, even a negative, attitude might embrace a positive gain, I have been induced to undertake a survey of the fruits of anthropometry in the hope that by clarifying its aims and its point of view I might thereby define its potentiality for those concerned with the qualities of populations.

But before making safari into the anthropometric jungle where physical anthropologists seek their quarry, let us first examine the nature of the quarry itself in the hope of explaining thereby the jungle which we must traverse. For I believe, to use less figurative language, that the aims of physical anthropology have shaped its means. What, then, are the aims of physical anthropology and how have they shaped the anthropometric means which we use in striving to attain them. In answer to this question I should like to sketch very briefly the history of physical anthropology for the benefit of the perspective it provides. We might begin in true Teutonic fashion by dredging in the wells of antiquity for the first mutilated fragments of Greek or Egyptian wisdom on the subject. We might, perhaps, with somewhat more justification consider the preoccupation of the renaissance painters and sculptors with the esthetic canons of the human body. But in reality we should find that physical anthropology as an organized discipline sprang from natural history and anatomy at a period when these as well as other sciences were less sharply differentiated than they are to-day. The catalytic agent responsible for its precipitation from the contemporary scientific solution was the problem of the racial classification of man. Bernier, in 1684, was perhaps the first modern to offer a racial classification. He divided mankind into four principal stocks: (1) Europeans, including with great liberality the north Africans, the Hindus and the American Indians; (2) Africans; (3) Asiatics; (4) Lapps. With the confidence of that innocent age Bradley, a professor of astronomy at Oxford, who looked through both ends of his telescope with equal ease, followed Bernier with a notable classification based on hair. Leibniz, the philosopher, added still another. But it remained for Linné in 1735 to give wide circulation to the idea of a racial division of mankind based on scientific observation. In this same period or immediately following we discover such illustrious names as Buffon, Kant, Maupertuis and Blumenbach associated with inquiries into the varieties of man. But these men, deeply read in the natural history of their times, employed the anecdotal and the subjective method in their lucubrations Even in more favorable circumstances their cabinets of cranial specimens were more often objects of curiosity and contemplation than of applied, systematic study. Leaving aside the investigations of human proportions for esthetic purposes which appear to be of greater interest in retrospect than they were in reality, one of the first impulses to achieve objective criteria in the classification of man came from Peter Camper, whose device of the facial angle was posthumously published in 1792. This angle measured the degree of facial prognathism and proved of enormous value in differentiating various groups of mankind.

The early nineteenth century successors of Blumenbach, who is frequently labelled the father of physical anthropology, included such men as Bory de Saint-Vincent, Pritchard, Nott, Glidden, Virey, Pickering and many others. They continued to depend largely on description and anecdote, although some unorganized data derived from objective measures were creeping into their learned and derivative literary monuments.

Towards the middle of the nineteenth century Carus in Germany and Morton in America appeared as exponents of a more exact and objective technique. Both these men were deeply stimulated by Lavater and Gall, whose discredited hypothesis on the association of character and cranial conformations have nevertheless proven fertile in a number of fields. By the middle decades of the century, the science of measuring the human body in an effort to establish criteria of race was already in a flourishing condition. To mention only a few outstanding workers, Retzius had invented the cephalic index, Virchow was busily engaged in measuring and describing skulls brought from the ends of the earth, Broca in France was laying the foundations of instrumentation and standards of exact measurement, and Quetelet was applying statistics to the measurements on the living body. The vast bulk of all these efforts still remained directed toward the elusive classification of man. This singleness of purpose continued with only an occasional lapse into alien territory down to the present century. It is true that the study of prehistoric man began to loom large in the middle of the last century, that evolution and the relationship of man to the primates captured the attention of the physical anthropologist after 1859, but these were in a sense only other aspects of the same taxonomic industry. For our immediate elders the culmination of this monogamous marriage of physical anthropology with race occurred when Martin in 1914 issued the first edition of his "Lehrbuch der Anthropologie," which later appeared in three heavy, exhaustive volumes. Here was summed up the science of anthropometry. Although Martin did not attempt to include every anthropometric measurement proposed or even employed up to that time, nevertheless he did pile up the impressive total of some 225 measurements and indices. One might suppose from this that the human body offered no additional dimensions and that nothing was left to measure, but, in addition to these, new measurements were and still are constantly being suggested with ever diminishing returns. Besides these strictly measurable characters, which include lengths, widths and girths of head, face, trunk and extremities, physical anthropologists also take numerous observations on non-measurable, or so-called qualitative traits, such as pigmentation of eye, hair and skin, form and distribution of hair and degrees of development of numerous anatomical features.

It must now be more than apparent that physical anthropology has been remarkably constant to a specific goal and that its technique was created mainly to serve that goal. Measurement after measurement has been added to uncover ever finer and more reliable criteria for racial classification. But the racial classification of man is essentially an anatomical one, concerned with gross external features and without consideration of quality or value. Just as the taxonomist in any zoological field regards his specimens without moral judgment, simply as ordered physical variants which can be made to fit into a pattern, so the student of race with some exceptions has striven to consider the varieties of man. His measures are purely physical ones and are not designed to give answers to questions of good or bad in quality, high or low in survival value, rich or poor in efficiency. Within normal ranges we can not say whether tall or short stature is preferable, whether dolichocephalic or brachycephalic heads are wiser, whether brown or blue eyes are keener, whether leptorrhine or platyrrhine people live longer or whether short- or long-trunked individuals are more efficient. Yet these are the kind of criteria upon which racial distinctions are based. It may be that some of the anthropometric measures have an index of survival value and may be rated as to quality. But if they can be so classified, the investigations of the physical anthropologist are not calculated to serve such a purpose. A little later I hope to mention the beginnings in this direction which hold forth promise for such future judgments.

Assuming for the moment that a racial classification of man is both necessary and feasible, and I believe it may be defended cogently, we may then ask if races are stable and preserve their identity through the ages and in differing environments. This seems to me not only a fundamental question for the understanding of race itself but of great importance in the problem of evolution. The first scientific investigation of this problem appeared some 25 years ago, when Professor Boas measured the children of immigrants to the United States. He discovered not only that the children born in this country underwent certain changes in stature and cephalic index but also that these changes were greater the longer the residence of the parents in this country before the birth of the child. These conclusions met with a storm of opposition and misinterpretation, and they failed to fertilize anthropological thought.

In 1930 on the invitation of the University of Hawaii I undertook to carry out some studies on the Chinese-Hawaiian hybrids. Such an investigation obviously demanded a knowledge of the parental groups, Hawaiian as well as Chinese. Since the Chinese were newcomers it was essential to know if they had suffered any physical alterations since their arrival in Hawaii, where living conditions are widely different from those in China. To insure an adequate genetic control I determined to investigate not only the Chinese immigrants to Hawaii and their children born in Hawaii but also their relatives in their native villages in China.

This study proved sufficiently promising to encourage its extension to the Japanese in Hawaii. In this latter group circumstances were even more favorable for such a study, because the immigration was more recent, the immigrants themselves more restricted in their origins and their relatives in Japan consequently more accessible for study. The Japanese in Hawaii were first introduced as labor on the sugar plantations. Two major waves occur in the general stream of migration The first appeared between 1884 and 1890 and the second reached its apex sometime around 1900. Laborers were recruited largely from the prefectures of southern Hondo, the main island of Japan, and from the nearby districts on the neighboring island of Kyushu. Our data on the Japanese fell into three main groups: (1) The Hawaiian born Japanese of pure Japanese parentage; (2) the immigrants born in Japan but migrant to Hawaii in early manhood; (3) the sedents, who are the relatives of the immigrants and represent the original population born and bred and living in Japan. I have adopted the term "sedents" because I could find no single word in English to describe those who, unlike the emigrants, remain at home. All three groups are of the same genetic lines.

The results of our investigation although not yet published are now available. They reveal, according to my interpretations, two phenomena of great significance. We have evidence here, I believe, of selection and of modification by environment. It is my belief that the immigrants represent a selected population, differing significantly from the sedents. In 37 out of 50 traits or in 74 per cent. of the comparisons the immigrants and sedents diverge to a statistically significant extent. The immigrants, compared with the sedents, have relatively shorter trunks, wider shoulders, narrower hips. Their chest is relatively wider and shallower. Their arms and legs are longer despite the similarity in total stature. Their faces are longer and wider at the level of the gonial angles. Their noses are longer and narrower. These are only some of the more striking differences between the two groups. Since both groups are intimately related by blood, and since both were born in Japan and raised to maturity there, the conclusion seems inevitable that the difference between them is the consequence of some form of selection. There was, however, no conscious selection on the part of the recruiters who merely accepted any able-bodied laborer willing to venture to Hawaii. It is, of course, clear that economic pressure played a significant part in inducing the immigrants to leave their native land. They were younger sons, landless and without prospects in their native country. It is easy to speculate on what might have been the fundamental selective factor which was able to gather out of a population so definite and distinctive a sub-type, but I shall leave that for another place. I wish merely to make the point here that the Japanese immigrants to Hawaii represent a deviant selected from the type most commonly encountered among the sedents.

When we come to assess the children of the immigrants born in Hawaii and raised under what we regard as far better environmental conditions, we discover a series of marked changes largely dependent on an increase in size. The Hawaiian born are 4.11 cm taller than their fathers; and although considerably younger than the immigrants they are heavier by four pounds; their trunks and legs are longer; their shoulders are wider. But it is necessary to note that these are all proportionate and harmonious changes, the indices remaining unchanged. In other words, the disproportions of the immigrants are maintained in the Hawaiian born, but modified by increases in bulk. But in addition to this increase in size combined with stability in proportion among the Hawaiian born when compared to their immigrant parents, we also observe a number of alterations in proportions largely concentrated in the cephalic and facial parts. Unexpectedly the head length decreased, despite an increase in stature and in bulk, while the head width increased, thereby causing the cephalic index to rise. This was a phenomenon observed in Boas's data. But in this wider setting the change is less characteristic. Without dwelling too long on the details of this investigation, I believe it demonstrates the manner in which populations may alter their racial characters. Their quantitative traits are subject to modification by selection and perhaps more significantly by environment, whatever that may be

Although physical anthropologists in general resist the idea that their races may be malleable under fluctuating conditions, many of their data support this hypothesis rather directly. For example, the progressive increase in stature of European populations has been noted by a number of investigators. In Germany, Sweden, France, England and America this phenomena has been demonstrated in army and college statistics. In this connection I must mention that the Japanese are also exhibiting increments in height, but these do not account for the prodigious jump in the Hawaiian-born Japanese, who far exceed their contemporaries in Japan.

Still another corpus or perhaps other corpora of data are susceptible to a similar interpretation, although other explanations have been offered. These are the studies which reveal that the more favored socio-economic classes and the urban dwellers in homogeneous and long-settled areas tend to differ from the surrounding population not only in their physical dimensions but in physiological traits such as onset of menses.

Before I pass on to another aspect of race I wish to make it clear that I am not defending an inherent capacity for unlimited change. All we have any right to suggest from the present data is that within certain limits a given racial group or stock may alter the dimensions of its physical characters and its proportions by a selective process or by modification induced by environment.

Having in this manner, by necessity briefly and elliptically, reviewed the history of racial investigation, described the creation of a technique to measure race, mentioned the recent trends in the study of race, it might well be asked what if anything does race offer us for the assessment of physical quality. I think the answer is clear from the preceding remarks. Nothing. The pursuit of a racial classification has been objective, concerned with visible, easily distinguishable traits subject to measurement either by calibrated instrument or by standardized scale. The physical anthropologist has never sought to determine whether the Polynesian is superior to the Malay, the Chinaman more enduring than the African or the whites preferable to the Mongols. He has only attempted to find the key to their classification by physical characters in order to establish their relationship and to understand their evolution. A certain class of unscientific and impressionistic writer, in almost every case non-anthropologists, who have sought to associate race with ideas of superiority and inferiority, are not, it seems to me, worthy of discussion in this company. On the other hand, the more serious attempts by psychologists to correlate race with psychological characters, especially the intelligence quotient, had a striking and apparently brief existence. Following Brigham's study of intelligence in the draft, hosts of disciples busily engaged themselves in plaguing tolerant but puzzled children and even uncomprehending savages with questions cleverly designed in the laboratory. The results of these earnest studies have been severely criticized by various writers.

Physiologists, however, have only made a beginning in the study of racial physiology. Such tests as the metabolic rate have been measured on a number of differing groups. Benedict, for example, finds that the Maya Indians have higher rates than North American whites, but that Chinese and Hindus have lower ones. As yet, however, these results are still tentative and have been denied in some quarters. Age at menarche shows some variation, but whether these fluctuations are racial or environmental is open to question. But the significant fact remains that the few physiological distinctions claimed to be correlated with race are not reliable criteria of quality.

It may, at this point, be pertinent to discuss briefly the nature of classification, as it affects the various efforts made to superimpose one system upon another. The efforts of physical anthropologists to classify man illustrate with exceptional clarity one of the difficulties of classification. So long as the criteria remained few the task was simple and satisfactory. All men could be neatly divided into large categories without distressing non-conformities and irritating exceptions. But with each addition to the battery of criteria the job becomes progressively harder. Instead of each new criterion correlating perfectly with the previous ones it tends to overlap and blur the previously established categories. Similarly physiological, psychical, psychological and social classifications refuse to fit exactly the racial classification. They overlap, they blur and they confuse. Each separate system is based on distinct criteria which may or may not be moderately correlated with race. But even if they were correlated, the correlation would never be perfect, and consequently to read the one by the other dangerous. It is here that the fundamental weakness of relying on physical race or stock for determining quality appears. Man, scientists not excepted, is prone to the easy fallacy of association. Presented with a classification of physical man, he soon seeks to squeeze all other systems into the same frame. If he finds, as he believes, that 60 per cent. of one racial category of mankind is established on farms and only 50 per cent. of another, then the former group is inevitably characterized as agricultural and the second non-agricultural, and if farmers happen to be the favored element in the population the second group has a rather rough time in the ensuing discussions. This is hardly an exaggeration. The literature is full of such examples of associational overlapping of disparate classification which in the resulting conclusions are treated as though the associations were complete and perfect. They hardly ever, I venture to say never, are.

I have, I hope, made clear that the technique of physical anthropology is designed to analyze physical race, which in turn is a purely zoological concept without connotation of quality; that race itself is subject to certain limited fluctuations dependent on selection and environment; that as yet we have no basis for correlating measures of physiology and psychology with race; that if we had, the physiological ones so far investigated are not susceptible to quality judgments, although the psychological ones might be so interpreted. But here lies the danger previously noted of incomplete association of one system with another, the danger of overlapping, which invalidates race as a final touchstone.

Thus in tackling race in an effort to reach the goal of quality judgments, we find the anthropometric studies of no assistance. What then can the physical anthropologist with his anthropometry offer the student of population who finds himself at an impasse? For, certainly, the population expert must wonder what his data signify in the future of his population. When he terrifies the lay public with charts of declining fertility, with graphs designed to show that the urban population is dying out, that the college population refuses to reproduce itself and that the Southern hill-billies threaten to replace the northern people, is he certain that the waning groups are actually better than the waxing ones. This is what the student of population really wishes to know and how to preserve these better elements if they really are superior.

I should like now to discuss briefly several lines of research which seem to me to offer some possibility of assistance to the questioning student of population. They represent recent developments in which physical anthropology has played a part. First, I shall touch on the study of constitution. The Kretschmerian association of body type with manic depressive and schizophrenic forms of insanity reopened an ancient, Hippocratic approach. Pende, Draper, Bauer, Krause and many others have carried this association of body build into the realm of disease. Draper, for example, claims a high degree of correlation between leptosome structure and gastric ulcer and between brachysome types and gall bladder disturbances. The underlying theory here is that deviant forms of body build create stresses and strains on correlated anatomical systems which thus become more liable to breakdown than others. Reed and Love have suggested similar associations. They found that T.B. is more common in tall, thin men than in short men, either thin or heavy. These authors also found that valvular diseases of the heart resulting from acute infectious and rheumatic fevers were more frequent in tall, thin men. It should, of course, be mentioned that these investigations of disease and structure are not universally accepted. Many of them have been based on extremely weak evidence and too few have been checked by other workers.

An interesting application of the concept of constitutional type appears in a study carried out by Bach. For example, gymnasts compared with men excelling in field sports were found to be short, heavy and broad, with large trunks; whereas the field athletes were tall, light in weight, narrow and long-legged. These differences appeared to be independent of racial or geographical factors. Similar conclusions were reached by Brezina and Lebzelter from a study of constitution and occupation.

The relationship of constitutional type to race is not altogether clear. Saller regards constitution as distinct from race and declares that races differ in the frequencies of the diverse constitutional types. Czekanowski and others concur in this opinion. And yet criticism has been directed toward the notion of constitution on the ground that it has confused the ideas of race and constitution.

Admitting the diagnostic value of constitution and accepting the claims that constitution and disease are associated, we still need to know whether or not constitution is a function of environment and whether it is correlated with race or geographical groups. We might, then, if not before, be justified in asking whether certain constitutional types are worse or better than others. And in response to this I know of no convincing studies. Perhaps some people would prefer to die of one disease rather than of another, but they would all be subject to *a* disease and eventually die. At best constitutional studies might tell us what diseases might be likely to attack certain people, but unless there is an age correlation I venture to suggest that in the health of the race it is not of paramount importance which disease is fated eventually to carry off the population. But should a scale of values be possible in grading the biological and social consequences of disease groups, then, always assuming the significant association of disease with constitution and constitution with biological groups of man, the qualitative aspects of these studies may prove of great value to the student of populations. But here as in other associations with race the correlation at best can never be perfect.

Before leaving this class of investigation I should like to mention another field of study which has some points of contact with constitution and some bearing on this discussion of the anthropometric approach to quality. I refer to the investigation of the rôle of the endocrines in the structure and function of the human organism.

At this stage in the progress of endocrinological research it would amount to supererogation to insist on the vital importance of the hormones in shaping not only our temperaments but our bodies as well. The vast amount of experimental work along these lines have amply demonstrated that. The consequences of the over-functioning of the pituitary in producing giantism, the effect of the gonads on sexual differentiation, the effect of hypofunction of the thyroid in a lowered metabolic rate are universally accepted. Dentists also are coming to recognize that the teeth are affected by disturbances in calcium metabolism. But the interrelation of the various internal secretions and their adjustments to the organism as a whole are enormously complex. Because of this interlocking system it is extremely difficult to isolate the essential nature of any one endocrine gland. In recent years huge strides have, however, been taken in the analysis of the endocrine function of experimental animals, but knowledge of the detailed relationship of the hormones with *human* structure and character has lagged behind.

Eleven years ago when I first began to take systematic measurements on various endocrine dystrophies, there were no objective data available on the effect of the endocrines on various anthropometric characters; and with the exception of Sir Arthur Keith's very general speculations on the interrelation of race and endocrines and Nikolaew's hypothetical remarks on the same subject nothing concrete existed on this suggestive interrelationship The possibilities for the understanding of human variations inherent in endocrine research have not yet been fully apprehended by physical anthropologists. I should like to cite in passing a few beginnings into this promising realm. Rowe has suggested that the hypo and hyper status of the various glands determine size and body proportion. The classic work of Tandler and Grosz and of Pittard on the Skotpsy, who are members of a cult which practices castration, revealed the profound effect which the gonads exercise in controlling the development of the body. Very recently Pearl investigated the weights and sizes of the endocrine organs in subjects from an insane asylum. Although his study does not fall within the frame of the present discussion of anthropometry, nevertheless his findings have some bearing on the problem. His general conclusion appeared to be that on a percentage basis of the whole endocrine system the insane were below normal in the gonads and thyroid and above in the others, particularly in the thymus, parathyroids and adrenals. No patterns were, however, discernible in the various psychiatric groups.

From the as yet fragmentary data on the influence of the hormones on body structure, one might hazard the opinion, without too much reliance on wishful thinking, that future research will reveal an interdependence of body structure and endocrines. Although the problem is more elusive, it is probable that temperamental as well as other psychological and intellectual attributes will similarly be found to be bound up with the ductless glands. Here is another avenue toward the eventual alliance of anthropometry, quality and population.

I have perhaps now arrived at a point where I may attempt to summarize what hope physical anthropology can at present hold out in determining quality in population. But before I do that I must first lay the ghost whose troubled ectoplasm has been hovering at this feast. I have quite deliberately refrained until now from discussing the fundamental question on which all this hinges. I had interpreted quite literally my premise and have sought to lay before you, negatively I am afraid, the anthropometric approach to the concept of quality of population. For purposes of introducing the physical anthropological philosophy I have assumed that we all know exactly what quality is. Remember, I speak only from the physical point of view, leaving aside questions of social behavior and intelligence, where perhaps the answer is clearer. If the human species were valuable as is the cow for its milk-producing virtues or as is the sheep for its fleece, then the problem of determining human quality would be much simplified. There is, of course, the all-too-human tendency to resolve the dilemma by regarding all who are different from oneself as of poorer and less desirable stuff—and by extension to even larger groups, for Nordics to belittle the Mediterranean, for whites to depreciate the Negroes and for man to deny the monkeys. Yet, as I have said before, what do we actually know of the relative virtues of the races of man, assuming it were possible to establish them in a hierarchy of physical virtue? We must, it seems to me, have a definite concept of what physical quality is before we can seek it and above all before we can measure it.

I shall with some trepidation and with considerable temerity make an effort to set up a definition of physical quality. Above all, it seems to me that physical quality should be characterized by efficiency. If the organism is ill-adapted to its function of living, it is poor in physical quality, whatever may be its intellectual capabilities. Lack of physical efficiency may, of course, be expressed in a great variety of ways, for example, in susceptibility to disease, lack of resistance to stress and fatigue, presence of abnormalities which interfere with function and of course mental incapacity. I have without any special research drawn up a list of commonly accepted factors which might seriously lessen physical efficiency: (1) Idiocy; (2) insanity, such as schizophrenia; (3) epilepsy; (4) blindness; (5) deafness; (6) chronic ill health; (7) malformity; (8) emotional instability.

You might perhaps be able to suggest other causes frequently found to interfere with physical efficiency, but they would in all probability fall into similar categories. I wish you to note that none of the commonly accepted disabilities just listed fall within the province of anthropometry, except perhaps malformity. In other words, if we measure poor quality by lack of efficiency, we discover that the very factors inhibiting efficiency are largely non-anthropometric. Because no one has ever sought to measure the relative physical efficiency of normal variations in human proportions, we do not know whether or not one type is a better machine than another. Here is a neglected field well worth cultivation.

To the definition of physical quality as efficiency we might also add survival value. But survival value, if interpreted to mean longevity, physical drive and fertility, likewise eludes the calipers. Its criteria are gauged by other methods than anthropometry.

I thus come to a rather negative conclusion when I state my belief that the immediate dangers of deterioration of population exist in characteristics not subject to or in most cases not amenable to anthropometric methods. In my opinion the traditional studies of physical anthropology—namely racial classification—have as yet nothing to offer of value in determining physical quality. But the chill of this negative may be tempered with the expectation that from the study of constitutional types and from investigations of endocrine control of human growth and development some light may be generated to clarify the definition and recognition of quality.

Finally, I can not forbear closing my remarks with a plea and a testimonial. I have discovered that the discipline of ordering my ideas for this paper, that the necessity of capturing nebulous dissatisfactions and of clothing them in words, has revealed a point of view of which I was previously only vaguely aware. I wish to make a plea for this point of view. I should like to see a reorientation in physical anthropology. Like the artist who finds it necessary constantly to refer back to life, the physical anthropologist must return to the living subject and reconsider him not as a static object but as a living dynamic, functioning organism. He must relate his data, his measurements, his proportions and his various traits and characters to the functions which gave them birth. He should seek to learn how all these anthropometric characters serve their organism, which are best suited for their task and what specifications make the best machine for a given purpose. We must create a whole new field of anthropometric research, designed to investigate the effect of normal as well as abnormal variations in human structure on the mechanics of the human organism. I would envisage a discipline in which health, physical vigor, longevity, fertility, physical efficiency were studied in terms of the functioning structure, not only physiologically and psychologically but anatomically as well. Perhaps if we achieve that, we may then serve the student of population.

THE COLORING OF FOOD: ITS USE AND ABUSE

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THE addition of color to food adds nothing to its nutritional value. In a few instances the color may appeal to the eye, but this appeal does not compensate for the many fraudulent purposes for which it is used.

Color is seldom used in the preparation of food in the household, except, for example, in the coloring of mint jelly and possibly in the coloring of frostings. In many instances the commercial use of color causes the food so colored to resemble the uncolored home-cooked variety.

Because of the possible fraudulent use of color in food, the statutes necessarily provide means of control. The coloring of food is occasionally permitted by law. The Massachusetts statutory definition of butter and cheese contains the following words, "and with or without coloring matter." All frozen desserts are, strange to say, required by the Massachusetts law to be colored, the definition of ice cream, for example, being, "a pure, clean, frozen product made from a combination of milk or cream or other milk product, with or without eggs, *but with* water, sugar, and harmless flavoring and *harmless color*, . . ." Those responsible for this definition did not apparently appreciate its real meaning, or the color addition would have been made permissive, as in butter and cheese. The courts, however, have not yet been called upon to convict a person for selling ice cream free from color.

The use of color in confectionery is impliedly permitted by the law, which prohibits the use of colors only if poisonous.

Color is not specifically mentioned in the Massachusetts milk law, but its use is prohibited by a statute penalizing the sale of milk containing any added foreign substance.

The Massachusetts statute specifically prohibits the use of color in the manufacture of sausages, it provides that vinegar is adulterated if colored, and it also prohibits the sale of oleomargarine containing any added coloring.

Apart from the above specific references to certain articles of food, the addition of color to food is governed by the General Food and Drug Law, which declares that food is adulterated, "Fourth, If it is mixed, colored, powdered, coated or stained in a manner whereby damage or inferiority is concealed." This is the wording of the United States law, of the Massachusetts law and of the law of most of the other states. The wording is not so satisfactory as was that of the old Massachusetts law, which it replaced. That law, found in Section 18 of Chapter 75 of the Revised Laws, now repealed, declared food to be adulterated, "Sixth, If it is colored, coated, polished or powdered in such a manner as to conceal its damaged or inferior condition, or if by any means it is made to appear better or of greater value than it is." Under the present law, it is not a violation to add color to food to make the article appear of better value than it is.

The human animal has many peculiarities regarding the color of his food.

The white versus brown egg obsession is one of these peculiarities, people in New England preferring the brown eggs presumably because most of the New England hens lay the brown variety, whereas people in New York prefer the white eggs because most of the hens in that locality lay the white variety. The white eggs from California are, consequently, shipped to New York and the brown eggs from California or from other states in the West are shipped to Massachusetts.

The preference in apples is for a red apple, although there are apples of different color which taste just as good.

When the golden bantam corn first came on the market it could be sold only with difficulty, because the consumer was of the opinion that it was field corn. It is practically impossible at present to merchandise the black Mexican corn, at least in New England, and there is no particular market demand for yellow tomatoes, although persons growing tomato plants in their back yards frequently purchase plants producing this type of tomato and in many back-yard gardens the black Mexican corn is now grown.

The colors used in food are usually of coal-tar origin and are known to be non-poisonous. The dyes selected for this purpose have been fed in extremely large quantities to animals without causing any untoward symptoms. The tinctorial power of these coal-tar dyes is far beyond what one not familiar with them can imagine.

The above statement brings to mind an incident related by one of my teachers, the late Professor James M. Crafts. He told the class that he saw at an exposition an enormous block of coal. Beside this were bottles containing the amount of benzene, toluene, etc., which could be obtained from that block of coal and also the very small amounts of certain dyes which could be made from these products of destructive distillation. Beside a small bottle of one of the dyes was a bolt of cloth which the dye could color, and this bolt of cloth assumed the gigantic size of the block of coal from which the small quantity of the dye could be manufactured.

Vegetable dyes are sometimes used to color food. One state formerly had a law prohibiting the use of coal-tar dyes in food, and a confectionery maker stated to me that it was necessary to add more than one per cent. of the total food in the form of vegetable color, in order to comply with this law and at the same time color the articles.

It is usually required that if coal-tar dyes are used for food purposes they must be certified dyes These dyes are specifically made for food purposes and consist of a small number of dyes of different colors. Each manufacturer sends to the U. S. Department of Agriculture a sample of each batch. This sample is then examined for the presence of possible impurities which may be dangerous, and if these impurities are found to be absent, the batch is then certified. This certification process does not apply to the vegetable dyes.

Confectionery has been colored for many years, and at present no serious harm results. Colors are frequently used to distinguish the flavors. For example, red gum drops are flavored with cassia or cinnamon; black gum drops are flavored with anise; mints flavored with peppermint are, strange to say, not colored, whereas other peppermint-flavored foods, as, for example, peppermint extract, are frequently colored green; wintergreen mints are usually colored red. Lozenges are frequently colored and some manufacturers place them in packages having a translucent cover so that the package presents a harmonious color scheme.

Color was formerly used as an adulterant of confectionery, but this practice ceased many years ago. One of the brown oxides of iron was occasionally used as a color in cheap chocolate to conceal the deficiency in chocolate. There is in the archives of the Massachusetts Department of Public Health a sample of Jordan almonds colored with lead chromate, otherwise known as chrome yellow. The last record of this form of adulteration resulted in two court cases during the year 1891. I am unable to state the result of these cases, but from information received from a person who has passed on, the late Albert E. Leach, former chief analyst, Massachusetts State Board of Health, the defendant in one case ate some of the lead chromate in the presence of the jury.

Color is occasionally used to give a definite article a uniform appearance The following information was received some years ago from a manufacturer of flavoring extracts. At first he did not use color in his vanilla extract, and naturally the different batches varied in color. Because of this variability consumers assumed that the light-colored extract was weak and the dark-colored extract was strong, which resulted in a discrimination against the lighter colored product. The manufacturer then obtained samples of a number of different batches of this extract and selected the darkest which apparently could be produced, to which he added a small amount of burnt sugar, otherwise known as caramel. This colored extract was then used as the standard, and all subsequent extracts were colored to match it. The public now gets from this manufacturer the same high quality of extract but uniform in color. There is no fraud in the use of color in instances like this.

It is also customary to color many of the other flavoring extracts. For example, a pale yellow is used in lemon extract, and an orange yellow in orange extract, etc. Some manufacturers have been omitting the color from these extracts and have labeled the packages to that effect. Persons using the uncolored extracts can identify them either by reading the labels or by removing the stoppers and smelling the material.

Color was occasionally used in milk in Massachusetts, but there has been practically none used during the past thirty years. The milk dealers using this color frequently paid fifty dollar fines for so doing. By persistent prosecution of these offenders the practice was found to be unprofitable and consequently it ceased.

Partly skimmed milk or milk containing added water to which a little coloring was added looked far richer than whole milk not so treated. The customer often complained to the milkman of the blue color of the milk after the removal of the cream for the morning coffee, and the customer often praised colored and watered milk which looked so rich after being skimmed. The milk trade defended this practice by saying that there was a demand for colored milk. This statement was true, but it was also true that this demand was created by the illegal acts of the trade. Since these illegal acts have ceased the demand for colored milk has gone. The color used was an alkaline solution of annatto sold under the very interesting name of "Milkman's Benefit," but occasionally a coal-tar dye of the methyl orange group was also used.

Sausages are sometimes colored, and the regulations of the Bureau of Animal Industry of the U. S. Department of Agriculture permits the practice under certain restrictions. The Massachusetts law, however, prohibits the use of color in the manufacture of sausages and prohibits the sale of colored sausages. Under these conditions, certain U. S. inspected and passed foods can not be legally sold in Massachusetts.

Color is used on smoked sausages of the frankfort and bologna type because it simulates the result of the smoking process and therefore reduces the time of smoking and also prevents the loss of water which would otherwise occur by a more prolonged smoking. On one occasion, when the department found color being used in U S. inspected frankfort sausages, it was believed that this was done because of the partial substitution of pork for beef. Paprika is frequently used in sausages of the frankfort type. Although paprika is a spice and may be legally used, its utilitarian purpose in this instance is because of its color.

One retail dealer used a very ingenious method to take advantage of his customers' color sensitivity. An inspector of the department saw in a showcase of a retail market some frankfort sausages which he believed were colored. He made a purchase and brought the sausages to the laboratory. When the package was opened in the presence of the inspector he was surprised to note that the sausages were not colored and the analysis subsequently showed his surmise to be correct. The inspector believed that the clerk in the store knew him and had substituted some uncolored sausages while wrapping the package. The inspector at once returned to the store and investigated. A red electric light bulb was concealed in the showcase, thus accounting for the observed color, which, however, was not considered a violation of the law. Another example of a similar use of color is a yellow milk bottle.

Color may be used in jams and jellies for legitimate or illegitimate purposes. Mint jelly is apple jelly in which some mint leaves are cooked, and the jelly is usually colored green even when made by the consumer. Apart from this, the use of color in jams and jellies is for fraudulent purposes and conceals the scarcity of the fruit of which the article is presumed to be made.

Tomato ketchup was formerly extensively colored until new methods of manufacture were developed which did not destroy to any great extent the natural color of the tomato, and at present many brands of tomato ketchup are not colored.

French peas were colored by boiling in a solution of copper sulfate. The copper combined with the albuminous material on the outside of the peas and produced a green color. The Massachusetts State Board of Health many years ago prosecuted a Massachusetts wholesale house for the sale of this variety of peas, alleging injury to health. The defendant put many reputable physicians on the witness stand, all of whom testified that the copper in the peas was not injurious to health. The case resulted in a finding of not guilty. Subsequent to this case, the importer continued to import and sell this variety of peas, but he took pains to label each package to the effect that the contents of the package were supposed to contain copper to an extent not exceeding a certain specified quantity.

One of the regulations of the U. S. Secretary of Agriculture is to the effect that copper can not be used in food on account of its alleged injurious action. This regulation has been adopted by most of the states, and while it may have no standing in the United States courts, it certainly has a standing in the state courts. The sale of vegetables artificially greened with copper is now practically nil.

The use of color is permitted in butter, cheese and ice cream, but it is prohibited in oleomargarine. The reason for the prohibition is very evident, as without the color oleomargarine can not be sold as butter. The argument in favor of adding color to butter is that there is no particular harm in making butter a little more yellow than it naturally is or in making butter produced in the winter months look like butter produced in the spring after the cows have been put out to pasture. This argument was formerly more valid than it is at present, because we now associate the presence of certain vitamins with the natural yellow color of butter.

After Congress placed a tax of ten cents a pound upon colored oleomargarine, the manufacturers naturally found difficulty in selling it uncolored because of its resemblance to lard. They then changed the character of some of the fats, and as one of the ingredients included June butter, which was naturally of a very heavy yellow color, they also used unbleached oils and selected oleo oil of a fairly heavy color, whereas prior to that time they used bleached oils and white oleo oil. If oleomargarine is colored, it can readily be sold as butter with but little complaint from the purchaser.

The presence of color in ice cream may cause it to look good. It may distinguish the different flavors, but a yellow color most certainly gives a creamy appearance often in excess of the cream concentration. In order to correct this deceptive appearance the statutes provide for a fat standard, in some states higher than in others.

The Massachusetts fat standard is 10 per cent., but the fat content of the average ice cream sold in Massachusetts is about 15 per cent. Ice cream with a very high fat content is naturally sold at a higher price than is ice cream with a low fat content, and therefore the addition of color does practically no harm because the consumer is getting about what he is paying for.

This argument regarding color in frozen desserts does not apply to sherbets. A mixture of sugar, water or milk, with a little citric acid, some oil of orange and a little color will resemble a superior article made from orange juice, sugar and milk or water, but will be a far inferior article because of the absence of the anti-scorbutic vitamin which makes orange juice so highly desirable.

Practically all soft drinks are colored, caramel being used in the dark beverages, such as sarsaparilla and root beer, a red color is used in the so-called strawberry or raspberry preparations, and the orange preparations are colored yellow. Most of the carbonated orange preparations consist of carbonated water, sugar, citric acid, color, a colloidal cloud and a little orange oil. These preparations are usually sold as orange soda, although some of them are mislabeled with the word "Orangeade." Orangeade, according to the dictionary, consists of orange juice, sugar and water. Because of this difference in the character of the two drinks, the consumer should learn to distinguish between the meaning of the two terms, orange soda and orangeade.

Another orange preparation, consisting of a little orange juice, somewhat less of lemon juice, sugar, water and color has been put upon the market in recent years, and its sales are apparently on the increase. Much of this material is sold by the milk dealers. The reason for the addition of the lemon juice is very interesting. Lemons contain six times as much citric acid as do oranges, and therefore for each volume of lemon juice in the mixture the manufacturer can save six times as much orange juice by the addition of sufficient sugar and water to take its place. Frequently citric acid is used in this preparation in place of lemon juice. The manufacturer will say that the lemon juice or citric acid is added to bring out the flavor of the orange juice, but it is difficult to understand this explanation when the analysis indicates a substantial reduction in total fruit juice. Many of these commercial preparations show upon analysis less than 15 per cent. of total fruit juice calculated as orange juice, but calculated from the citric acid and sugar content alone show the equivalent of 30 per cent. of orange juice.

The U. S. Department of Agriculture has recently made a ruling to the effect that the interstate shipment of these preparations, if colored, and even so labeled is a violation of the Food and Drug Law. This regulation has no force before a United States Court. The United States has made no prosecutions, but the interstate shippers have been sending the concentrated material in interstate commerce without the addition of color and have sent the color in another package with the intention of having the retailer add the color and take his chances with the state food enforcement officials. A representative of one of these interstate shippers was asked why not ship in interstate commerce some colored orange concentrate and invite federal action. He replied because of multiple seizures, together with the expense of defending all of them. I am aware of no court decisions upholding the above ruling. A case should be tried in the U. S. courts and the ruling should not be passed on to the states for enforcement.

Some Massachusetts dealers omitted the color, and several milk dealers who did so claimed a loss in trade to competitors who sold this material with the color added. As this loss in trade was also accompanied by loss in milk business, the dealers were somewhat provoked. It is rather strange that the addition of a small amount of color to a food preparation would have such an effect upon its salability.

There has recently developed a practice of coloring oranges. This is carried on to the greatest extent in the State of Florida. Persons usually judge the ripeness of an orange by its color. Citrus fruits do not ripen after being picked from the tree, and in this characteristic they are different from many other fruits, which can be picked green and which will ripen in transit.

The representatives of the Florida orange industry state that all ripe fruit is not yellow and, unless colored, the consumer will not purchase it. The organization claims that by their process of commercial handling no fruit is colored except fruit that is ripe According to the regulations of the U. S. Department of Agriculture, each orange which is so colored must be labeled upon the skin to that effect.

Not only soft drinks but hard drinks as well are frequently colored. Wines depend for their color upon the color of the grape skins from which they were manufactured, but a great many years ago the Massachusetts Department of Health had occasion to prosecute a man for selling a wine fermented from commercial glucose to which had been added some salicylic acid and some artificial color. This, however, is unusual. Distilled liquors of the gin or schnapps type are not colored. Many of the cordials are colored, and this is also true of practically all the whiskey. Freshly distilled whiskey is white. If it is placed in an oak barrel for the purpose of being aged, it absorbs color from the barrel. If the barrel is charred on the inside, as is the custom in the United States, the whiskey in addition absorbs the color produced by the charring process. If the whiskey is a blend, it is diluted and flavored alcohol, to which may be added some aged whiskey, and the mixture is then colored with burnt sugar.

Color is sometimes used in olive oil sold to the Italian and Greek people. For some reason, these persons prefer a green olive oil, and the green color is frequently added to cottonseed oil mixtures containing a small amount of slightly rancid olive oil.

Chopped meat is often colored by the addition of sodium sulfite. This practice is permitted by the Massachusetts statutes, provided that the sodium sulfite content is not in excess of one tenth of one per cent. and provided further that the presence of this chemical is made known to the purchaser by an appropriate label on the outside of the package. This material is sometimes added to fresh beef sausage, and by the Italians to fresh pork sausage. Red meat darkens upon exposure to the air. The sulfite reacts with some of the constituents of the meat proteins and produces a red color which makes the article look like fresh meat. The sodium sulfite also acts to some extent as a deodorizer, but its preservative properties are too slight to be of any practical value.

Sodium nitrate, otherwise known as saltpeter, and more recently sodium nitrite, are also used in curing meat. During the process of curing, the nitrate if used is reduced to nitrite at the expense of some of the meat; consequently, the addition of sodium nitrite is now permitted by the regulations of the U. S. Bureau of Animal Industry. Meat cured in this way will develop a red color on cooking, and the flavor is somewhat different from that of meat cured with salt. Some people like it, others do not. The meat so treated is usually sold as being saltpeter cured.

Cake made by bakers is sometimes colored yellow in order that the consumer may imagine that it contains more eggs than are actually used.

Color was formerly used to cover up certain types of adulteration now obsolete. For example, charcoal was mixed with black pepper, adulterated so far with starch that it was necessary to add a little cayenne to give it a kick. Mustard, diluted with more than half its weight of wheat flour, was colored with turmeric, and so-called custard powder, consisting of tapioca starch, was sold in two packages, one, not colored, representing the egg white and the other, colored yellow, representing the egg yolk.

Nearly forty years ago I heard the late Dr. Samuel W. Abbott, secretary of the Massachusetts State Board of Health, say to a legislative committee: "Gentlemen: If you pass a law prohibiting the use of color in food you will do more to stop food adulteration than by any other means." Even to-day there is considerable truth in that statement.

THE ELECTRICAL STATE OF THE EARTH'S OUTER ATMOSPHERE

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On August 25, 1936, shortly after noon, the pilot of an airliner in South America found that radio signals from his base at Lima, Peru, some 200 miles north, had suddenly disappeared. From 1:26 P.M. until 2:43 P.M. absolutely no communication could be effected on any high radio frequency. At Seattle, Washington, a radio operator, who was communicating with ships at sea, reported that at exactly the same time ship-to-shore communication on the high radio frequencies dropped out entirely and remained impossible for more than an hour. Subsequent investigation showed that throughout the central portion of the sunlit hemisphere all high-frequency radio circuits were simultaneously interrupted during the same interval.

CLOSELY RELATED PHENOMENA

This wide-spread interruption of radio services was only one part of a far-reaching effect. At Huancayo, Peru, the Institution's Department of Terrestrial Magnetism maintains a magnetic observatory to record the strength and direction of the earth's magnetic field, the electrical currents in the earth's crust, the electrical state of the upper atmosphere and other related geophysical effects. Observers there noted that at precisely the same moment, that is, 1:26 P.M. (Eastern standard time), the earth's magnetic field suddenly increased in intensity, simultaneously shifting its direction slightly. Likewise the currents in the earth's surface fluctuated violently. Investigation shows that these effects were observed throughout the central portion of the sunlit hemisphere.

Regularly scheduled observations of the sun were commenced a few minutes later by observers at the Mount Wilson Observatory of the Carnegie Institution with the spectrohelioscope. To quote from Dr. Richardson's report:

> On August 25 a brilliant sunspot-eruption was first seen on a hydrogen spectroheliogram taken at $18^h\ 58^m$. (This was 1: 58 P.M. eastern standard time.) No observations are available for an hour preceding this time. . . . Successive exposures taken at intervals of four minutes . . . show the flocculi decreasing in brightness until about $19^h\ 22^m$ (2: 22 P.M. eastern standard time), when the appearance of the region was normal. This fade-out and sunspot-eruption resemble those of April 8, 1936, when the phenomena were observed to occur simultaneously. We can not definitely establish that the fade-out and eruption of August 25 were simultaneous, but from our knowledge of sunspot-eruptions it does not seem unreasonable to assume that the outburst may have begun about $18^h\ 30^m$ since 28 minutes later it was definitely on the decline.

The recent discovery by Dellinger and by Jouast that radio fade-outs of wide-spread influence occur in the sunlit hemisphere has been followed almost immediately with the recognition that they are accompanied by solar and magnetic effects which have been described. On April 8, 1936, such an occurrence was observed in all its phases by the observers at the Huancayo Magnetic Observatory. Fig. 1 shows the simultaneity of these events at this observatory. The spectroheliograms of the sun have been kindly supplied by the Mount Wilson Observatory because photographic methods are not available on the spectrohelioscope at Huancayo. Mr. Scott, who was observing on the spectrohelioscope at Huancayo at this time, witnessed the commencement of this solar eruption and, realizing its unusual character, hurriedly called Mr. Torreson, the observer-in-charge. Both agree that it was one of the brightest eruptions which has been observed at Huancayo.

Here, then, we have examples of effects observed on the sun and simultaneously on the sunlit hemisphere of the earth, including a brilliant sunspot-eruption accompanied by a cessation of high-frequency radio communication and violent fluctuations in the earth's magnetic field and in currents flowing in the earth's crust. The question arises—how is it possible for an eruption on the sun to have such wide-spread effects on the earth? What is the physical mechanism by which such an eruption can interrupt radio communication, can change the force and direction of the earth's magnetic field, and can affect currents flowing in the earth?

The example which I have cited describes only one type of the numerous relationships which we know to exist between solar changes and terrestrial effects. It was realized as early as 1843 by Schwabe of Dessau that the number of sunspots varied systematically over a period of about 11 years, that is, the time-interval between the occurrence of minimum numbers of sunspots. As the numbers of sunspots vary, the magnitude of fluctuation and frequency of disturbance of the earth's magnetism changes similarly, so that magnetic activity is greater when sunspots are more numerous. The auroras and earth-currents are related in a like manner to solar and magnetic activity. Then there is the 27-day recurrence tendency. If a magnetic disturbance or a severe radio disturbance occurs to-day, it is probable that one will occur 27 days from to-day, and perhaps again 54 days from to-day. Now this period of 27 days is the average time required for a sunspot to rotate from a position toward the earth, around the sun, to a position toward the earth again.

All these facts show that not only are magnetic activity, radio transmission, auroras, earth-currents and similar phenomena closely related, but they are also related definitely to events, some visible and some invisible, which occur on the sun. We must again repeat the question—what are the physical mechanisms by which events on the sun have such wide-spread influence on the earth? What is the nature of these emanations from the sun which cause these terrestrial reactions? Such questions have been troubling investigators since the inception of studies in meteorology and terrestrial magnetism.

ATTEMPTS TO EXPLAIN RELATIONSHIP

A start toward the proper solution was made with the masterly mathematical developments of Gauss just about a century ago when he showed how it was possible to separate the magnetic field of the earth into two parts—one part originating inside the earth and the other originating in regions external to the earth's crust. Not enough magnetic data from widely separated locations were available at this early date to permit him to conduct the actual operation for the variations of the earth's field. His work did, however, greatly stimulate the construction of magnetic observatories which made such a separation of the magnetic variation-field into its internal and external sources eventually possible.

In 1882, Profesor Balfour Stewart published the first suggestion that daily fluctuations in the earth's magnetism must arise from an electrical condition in the earth's outer atmosphere. He proposed that this electrified outer atmosphere formed the bond between effects on the sun and the related geophysical changes which were observed on the earth.

It is worth while to read from Stewart's conclusions. He says:

> We are thus driven by the method of exhaustions to look to the upper regions of the atmosphere as the most probable seat of the solar influence in producing diurnal magnetic changes, and it need only be said that the only conceivable

> magnetic cause capable of operating in such regions must be an electrical current. Now we know from our study of the aurora that there are such currents in these regions. . . . A good deal has been said about the difficulty of imagining a daily set of currents to be generated in the regions of such imperfect conductivity but . . . there seems ground for believing that their conductivity may be much greater than has heretofore been supposed.

Balfour Stewart thought, however, that the electrical conditions affecting the earth's magnetism must exist at about the upper cloud-level, which we now know to be much too low. Sir Arthur Schuster succeeded Balfour Stewart as professor of physics at Manchester in 1888, and a year later he published the results of a mathematical analysis conducted along the lines which had been earlier suggested by Gauss. In this, he conclusively proved that certain variations in the earth's magnetic field must originate in a region exterior to the earth's crust.

The conclusions of Stewart and Schuster found only limited circulation outside their field, so that in 1900, when Marconi made his first transmission of radio waves across the Atlantic, engineers were at a loss to know how radio waves were bent around the earth. It appeared that as radio waves were of the same nature as light, they should travel off into space at a tangent to the earth. In 1902, Professor A. E. Kennelly, of Harvard, and O. Heaviside, an English engineer, both apparently unaware of the earlier deductions from terrestrial magnetism, independently proposed that an electrically conducting region must exist in the earth's outer atmosphere which reflected the radio waves back to the earth. This is the well-known "Kennelly-Heaviside layer" designated by the more general name "ionosphere." Professor Kennelly tentatively assigned a height of about 80 kilometers (50 miles) to this region, a height since shown to be very nearly correct.

Here, then, were two independent phenomena—terrestrial magnetism and radio-wave transmission—each of which required the existence of an electrically conducting region in the upper atmosphere to explain its effects. It now but required the tools to prove directly the existence of such an electrified region in the outer atmosphere and to show its characteristics. This problem was undertaken simultaneously by Appleton and Barnett in England, by Breit and Tuve, of the Department of Terrestrial Magnetism in Washington, and by Taylor and Hulburt, of the United States Naval Research Laboratory in Bellevue. Each group used a different method.

The method of Breit and Tuve was the most simple and direct, and now almost universally forms the basis for modern methods of ionospheric measurement. They reasoned that if the ionosphere was at about 100 kilometers (60 miles) in height, it would take about six ten-thousandths of a second for a radio wave, propagated at the velocity of light, to travel up to the ionosphere, to be reflected and to return to the earth. Then if a pulse of radio waves of a much shorter duration, perhaps one or two ten-thousandths of a second, were transmitted upward, the reflection should be returned and observed quite distinctly a few ten-thousandths of a second after the transmission had been completed. The experiment was conducted between the Department of Terrestrial Magnetism and the Naval Research Laboratory. Not only were definite reflections observed from the ionosphere, but they were of such character as to indicate that a complex electrical structure must exist.

This, then, forms the basic experiment around which the structure of our modern studies of the ionosphere have been erected. It establishes definitely that the outer atmosphere must contain electrically charged particles in large numbers, which is exactly the condition required to explain the efforts of terrestrial magnetism and radio transmission.

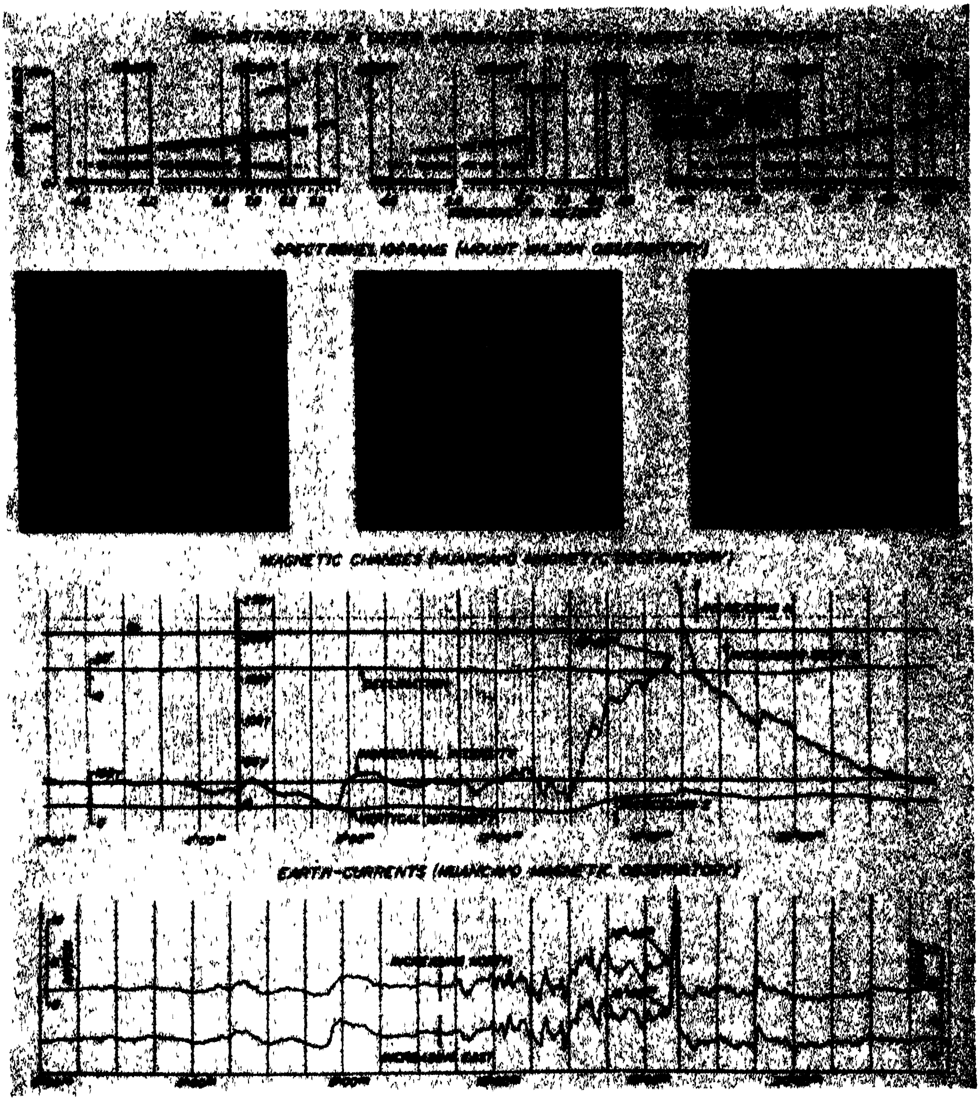


FIG. 1. MAGNETIC, RADIO, AND EARTH-CURRENT DISTURBANCES ASSOCIATED WITH THE BRILLIANT SOLAR ERUPTION OF APRIL 8, 1936.

EXPLORING THE IONOSPHERE

With the reality of the ionosphere established, the question arises—what is the mechanism within this medium through which the sun influences terrestrial magnetism, radio transmission and the other effects which we have mentioned? The answer to this question is the objective of modern research into the electrical state of the upper atmosphere.

To obtain the answer it is necessary that we first learn how these electrically charged particles or ions are distributed through the outer atmosphere. What is the density of ions at each height above the earth and how does this density change from hour to hour, day to day, season to season and year to year? Furthermore, we must learn something of the physical structure of the outer

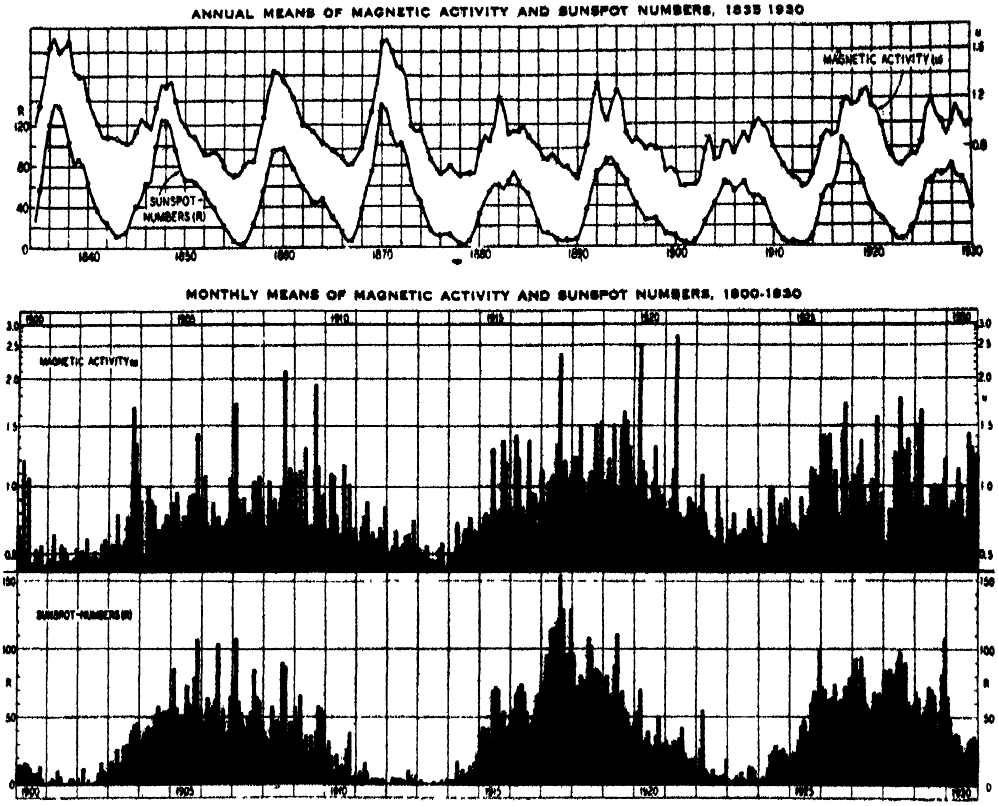


FIG. 2. MAGNETIC ACTIVITY IN RELATION TO SUNSPOT NUMBERS.

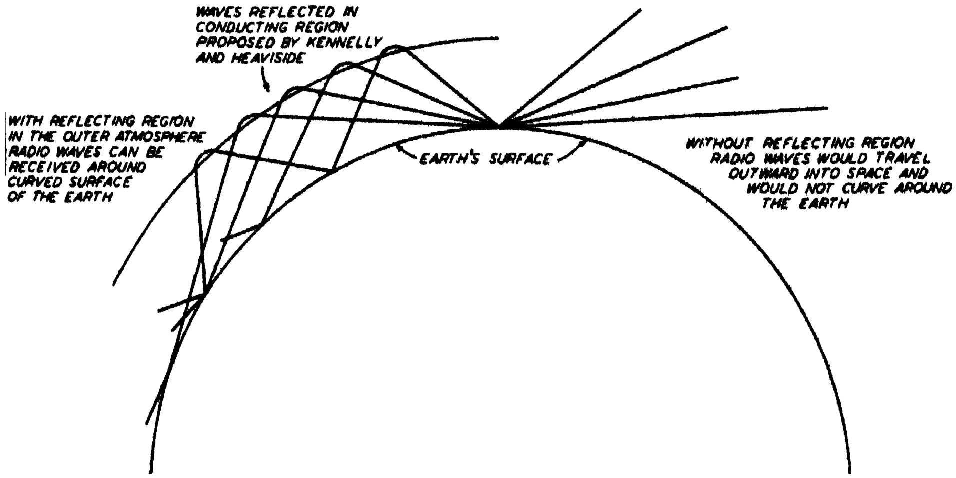

WAVES REFLECTED IN CONDUCTING REGION PROPOSED BY KENNELLY AND HEAVISIDE
WITH REFLECTING REGION IN THE OUTER ATMOSPHERE RADIO WAVES CAN BE RECEIVED AROUND CURVED SURFACE OF THE EARTH
EARTH'S SURFACE
WITHOUT REFLECTING REGION RADIO WAVES WOULD TRAVEL OUTWARD INTO SPACE AND WOULD NOT CURVE AROUND THE EARTH

FIG. 3. EARLY RADIO EVIDENCE FOR AN ELECTRICALLY CONDUCTING REGION IN THE OUTER ATMOSPHERE.

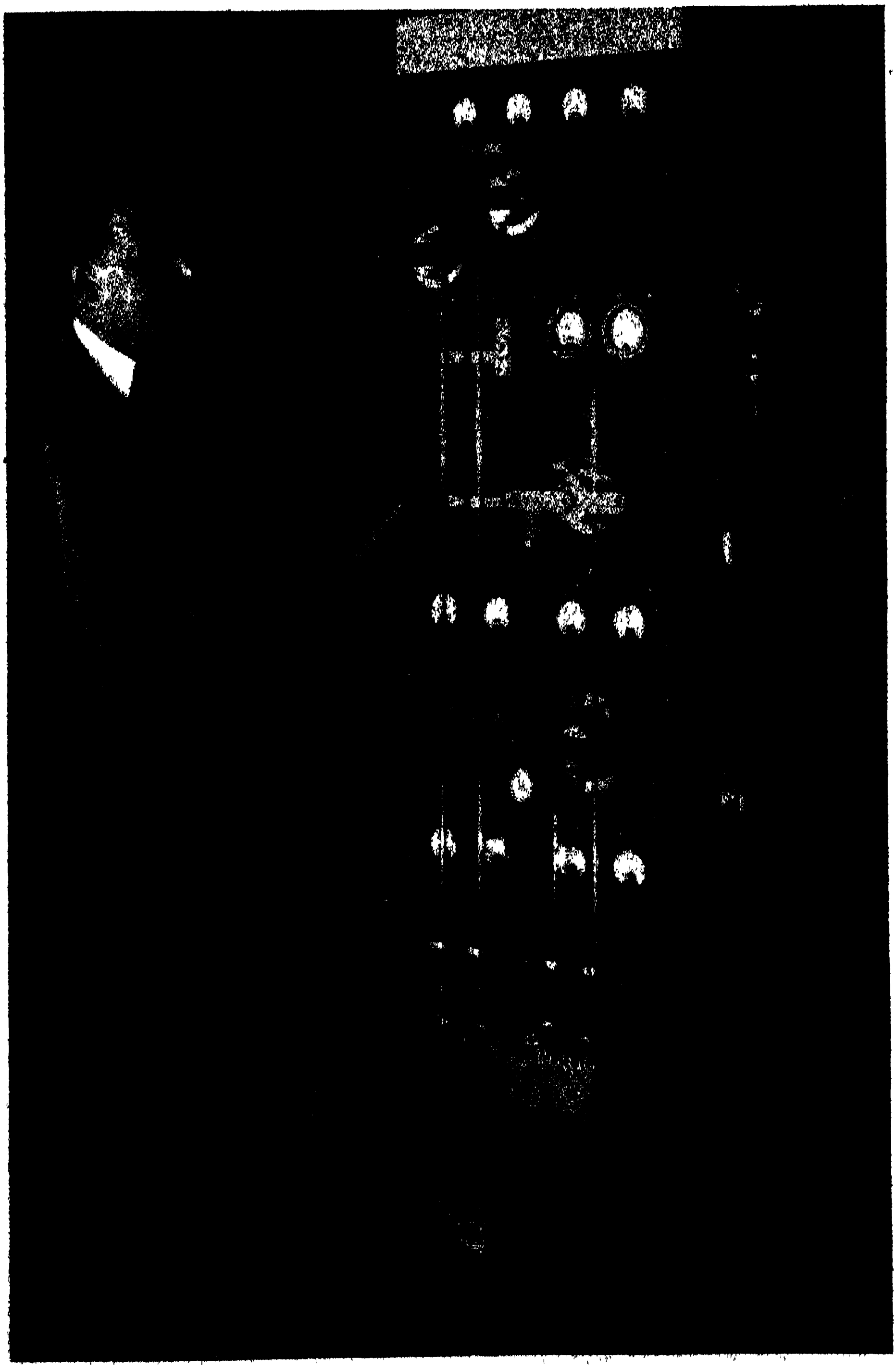


FIG. 4. MR. BERKNER DEMONSTRATING FINAL AUTOMATIC MULTIFREQUENCY EQUIPMENT FOR DETERMINATION OF ION-DISTRIBUTION IN IONOSPHERE.

atmosphere, of its constituent molecules and atoms, of its temperature.

Before discussing these things, permit me to preface my remarks with a brief description of the radio method by which many of them are determined. To observe the number of ions at each height throughout the upper atmosphere, the experiment of Breit and Tuve has been extended.

You may recall that in their experiment a pulse of one or two ten-thousandths of a second was sent upward and the height of the reflecting level was determined from the time required for the reflection to return. Suppose, for instance, that we wish to know our distance from an inaccessible cliff. If we make a loud noise, as by firing a gun, we will hear the echo return. Now sound travels one mile in 5 seconds, so if the echo comes back 5 seconds later we know that the sound has traveled one mile and that the cliff is therefore half this distance or one half mile away.

In this analogy, the radio transmitter is the gun and the sound becomes the radio wave traveling at the constant velocity of light throughout virtually all its path (300,000 kilometers or 186,000 miles per second). As a consequence, the echo-time is very short—it requires about one one-thousandth of a second for the wave to travel to a height of 100 miles and return. Thus we can determine the height from the travel-time for the transmitted pulse.

Now the number of electrically charged particles, or ions, which cause the wave to be reflected depend upon the characteristics of the transmitted radio wave. If the pulse of radio waves is transmitted directly upward, this characteristic is simply the frequency of the wave, that is, the number of complete oscillations which the wave executes per second. A wave of a low frequency such as 900 kilocycles per second—a frequency in the broadcast band—will be reflected when it encounters a density of 10,000 electrons per cubic centimeter directly above the transmitter (see Fig. 5). Then if we measure the height of the reflecting level on a frequency of 900 kilocycles per second, we are in reality measuring the height at which a density of 10,000 electrons per cubic centimeter exists.

If we make our measurement on a higher frequency, the wave is more penetrating or we might say that the ionosphere "looked" more transparent to this wave. Therefore, a higher ion-density, that is, a larger number of electrical charges per cubic centimeter, is required for reflection. For instance, a transmission upward on a frequency of 9,000 kilocycles per second will travel until it encounters 1,000,000 electrons per cubic centimeter before it is reflected. If such a high density of ions does not exist, the wave can not be reflected but will continue to travel into outer space and will be lost. Then for each frequency there is a definite number of ions which will reflect the wave at normal incidence.

This, then, gives the method by which the numbers of ions at each height can be determined. In practice, a measurement of height is made first on a low frequency. The wave is reflected when it encounters the value of ion-density which corresponds to that frequency, so the height of this ion-density is determined. Then the frequency is increased slightly and another measurement made. This gives the height of the slightly higher ion-density which corresponds to the new frequency.

As measurements are made on higher and higher frequencies, the heights of larger and larger ion-densities are determined until finally the frequency is increased to a value at which it is so penetrating that it can not be stopped by the highest value of ion-density which exists in the region. This frequency is called the "critical frequency," for it tells us the highest density of electrical charges which occurs in the region. Now the measurements on all these frequencies, when combined, give the height of each value of ion-density, and therefore

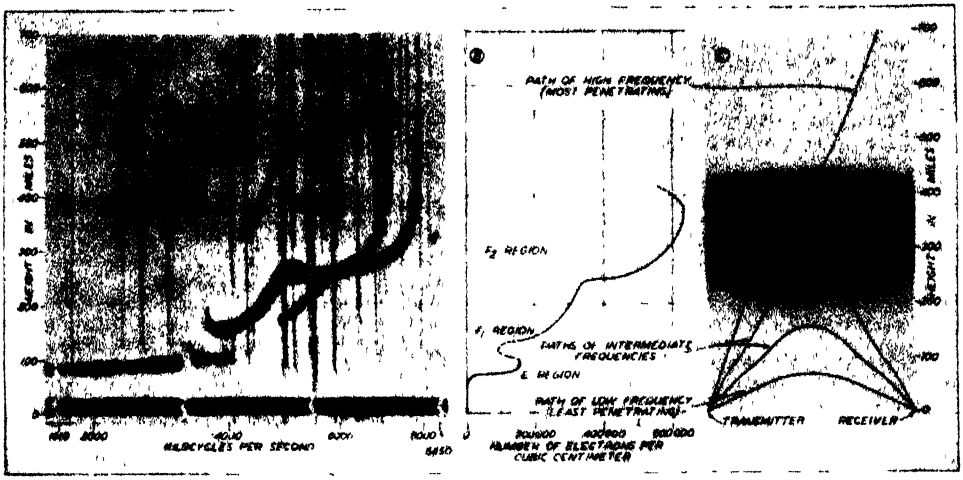


FIG. 5. SHOWING RESULTS OF EXPLORATION OF THE IONOSPHERE. (A) TYPICAL RECORD OF HEIGHTS OF ION-DENSITIES; (B) DISTRIBUTION OF IONS DEDUCED FROM (A); (C) SHOWING PATHS OF WAVES OF VARIOUS FREQUENCIES.

the distribution of ionization through the outer atmosphere.

In the earlier equipment these measurements at successively greater frequencies were conducted by an operator who made each adjustment of frequency manually and who then measured the height of each ion-density visually on an oscilloscope. Such methods were slow and cumbersome. A highly experienced observer required from one to two hours to make a complete determination of the distribution of ionization through the whole of the ionosphere. During this interval the ionosphere might have changed very materially. The first improvement was to record the results photographically. Even then continuity of measurement by such a method is impossible without an unreasonably large personnel.

The necessary simplification of procedure has been attacked at the Department of Terrestrial Magnetism. During the past year an automatic equipment has been completed which makes a record of the entire distribution of ionization throughout the outer atmosphere in 15 minutes. The equipment operates continuously without attention so that four complete records are available each hour. In its design the suggestions of Gilliland have been incorporated to synchronize the transmitter and receiver Those of you who attended the annual exhibition of the Carnegie Institution during last December may recall that the automatic equipment of this type which is to be placed at the magnetic observatories of the Department of Terrestrial Magnetism was demonstrated there.

The automatic equipment, however, is the result of a long research only now nearing completion. In the meantime it became evident that to understand the vagaries of the ionosphere, measurements must be made at a number of locations over the earth. These were in the nature of preliminary experiments to determine the nature of the problem and to guide the design of the final equipment so that its ultimate requirements might be fully met. To accomplish this purpose more simple, if less complete, manual equipment was sent into the field. One such unit is located at the Huancayo Magnetic Observatory of the department.

Huancayo, Peru, is about 12° south of the equator and almost directly south of Washington near the 75th meridian. This location is on the magnetic equator position of considerable importance, as will be seen. A second unit is at the Watheroo Magnetic Observatory of the department, about 30° south of the equator at 116° east longitude. These stations, in conjunction with the station of the National Bureau of Standards at Washington with which close cooperation is maintained, have made possible a comprehensive approach to the world-wide aspects of the ionosphere. In the ensuing material I have drawn freely from the excellent published data of the Radio Section of the National Bureau of Standards, particularly of my former associates Kirby, Gilliland and Judson, to make the world picture more complete.

REGIONS OF IONIZATION

We find that the ionosphere is not a simple region of ionization, as was first thought. The original experiments of Breit and Tuve indicated a complicated structure, and early experiments of Appleton showed that two regions must exist. Now we know that it consists of two and, under some conditions, three major regions of ionization. The lower of these regions, technically known as the E-region, is around 100 kilometers (about 60 miles) above the earth's surface, while the upper regions, technically known as the F_1- and F_2-regions, are around 210 kilometers (about 125 miles) and 300 kilometers (about 180 miles) overhead, respectively. These are average values, as the heights vary a good deal under different conditions.

Before we examine these regions in greater detail, let us observe another characteristic of the reflected waves. You will have noticed that certain parts of the curve divide into two branches (Fig. 5); a closer examination discloses that there are really two separate sets of curves, one displaced to the right of the other. This effect appears because of the presence of the earth's magnetic field in the ionosphere and was predicted from mathematical equations before the effect was actually observed. Those of you familiar with physics will recognize it as the Zeeman effect.

Now the waves reflected back from the ionosphere have different charactersitics for each of these branches. Under ordinary circumstances these are quite complicated and we say that they are elliptically polarized. At Huancayo, on the magnetic equator, the earth's field is horizontal overhead and the waves travel at right-angles to this field. According to the theory, the nature of the reflected waves should be much more simple or, as we say, "plane polarized." This matter was examined at Huancayo in experiments conducted by my colleague, H. W. Wells, and they were found to have exactly the nature which the theory predicts.

This effect not only permits confirmation of the theory of reflection but can be used as a tool to study directly the strength of the earth's magnetic field at great heights. It may be that through this mechanism it will be possible eventually to measure small fluctuations of the earth's field in the ionosphere with a highly developed technique. Such an experiment would be of first importance in determining the exact level at which magnetic fluctuations arise.

Imagine traveling upward on a summer noon at Huancayo in some conveyance which could take us to the outer reaches of the atmosphere. Near the earth we find a few thousand ions per cubic centimeter, due to cosmic rays and other sources. From about 25 kilometers (15 miles) to about 65 kilometers (40 miles) we travel in a region in which little is now known concerning the ionization from actual experiment, though it must be relatively low.

At a height of about 65 kilometers we observe the density of ionization to increase, gradually at first and then with increasing rapidity. At about 100 kilometers (60 miles) the increase becomes so sudden that the density of ionization changes by a factor of ten or more within a few kilometers. A little above this,

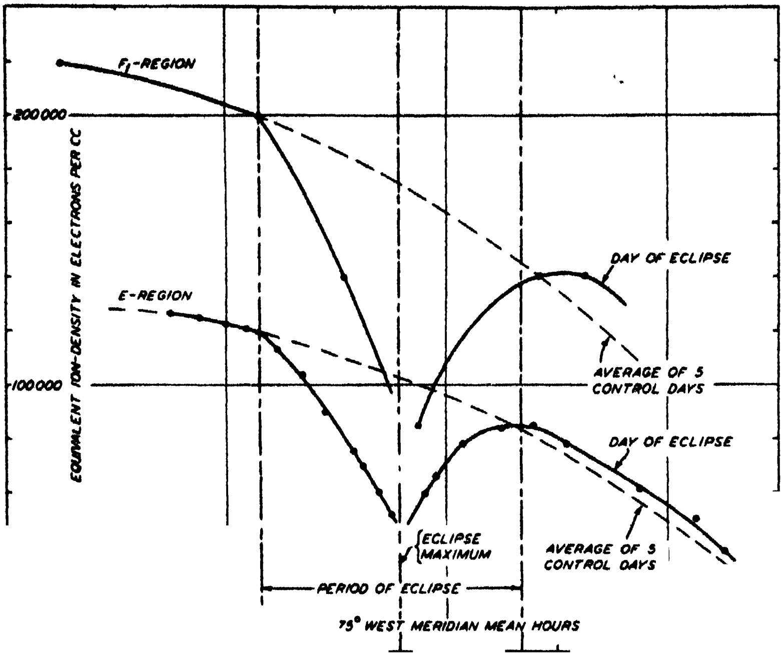


FIG. 6. SOLAR ECLIPSE EFFECT IN E- AND F$_1$-REGIONS ON AUGUST 31, 1932, KENSINGTON, MARYLAND. AS THE SUN'S DISK WAS OBSCURED, IONIZATION IMMEDIATELY DECREASED, AGAIN INCREASING AS THE SUN CAME INTO VIEW.

about 110 kilometers (65 miles), we reach the maximum density corresponding to about 180,000 electrons per cubic centimeter. This is the E-region of the ionosphere.

The change just below this height is abrupt, and therefore the term "layer" is sometimes applied. Just above this there is evidence to believe that the ion-density decreases slightly. Then it increases again—very rapidly at a height of about 190 kilometers. The maximum is reached somewhat above 220 kilometers (say 130 miles), where we find that the ion-density corresponds to about 330,000 electrons per cubic centimeter. This is the F$_1$-region. As we continue upward the ionization remains nearly constant, though it may decrease or increase a little, until at about 300 kilometers (say 180 miles) a third sharp increase occurs. The density of ionization near this level may reach as much as 1,000,000 electrons per cubic centimeter.

It must be remembered that this distribution is for a particular time of day, season and year, and that under other conditions the situation might differ materially. Nevertheless, the first two regions at about 100 kilometers and at about 220 kilometers will be found over any part of the earth as far as we now know, though the maximum densities might differ tenfold.

We have spoken of two regions being present always—the third has a more transient existence. This third, or F$_2$-region, exists separately only under the more direct rays of the sun. It appears to bulge outward from the next lower or F$_1$-region. This bulge seems to center directly under the sun, so that at this point the F$_2$-region is in general highest and most widely separated from the F$_1$-region below. If we move away in any direction, the height of the upper region falls until it finally merges with the region below. The separation between the two regions is scarcely distinguishable in a position where the sun's altitude is less than about 45°. Therefore, the F_1- and F_2-regions appear separated only in a circular area under the sun and consequently are in the center of the sunlit hemisphere. This bulge covers an area of about three tenths the sunlit hemisphere Where the two regions merge at the outside edges of this bulge, the resultant region is known simply as the F-region Because their ionizations add together, this new region has many of the characteristics of the more highly ionized F_2-region.

Because the earth's axis is tilted about 67° with respect to the plane of its orbit, the center of this area rotates around the earth with the sun along the Tropic of Cancer in the northern summer, gradually shifting to the Tropic of Capricorn as the seasons reverse. At Washington, for example, the separation of these upper regions is quite distinct during the midday hours in the summer when the sun reaches an altitude of about 78° above the horizon, but in midwinter these regions are entirely merged because the sun reaches an altitude of only 28° at midday, when Washington is well outside the 45° zone.

We see, then, that instead of the simple region which was originally conceived, the ionosphere is complicated, involving two main regions with a tremendous bulge above the upper of these to form still a third region of ionization. Why should three regions exist? What is their origin?

ORIGIN OF IONIZED REGIONS

We can learn something of this from the characteristics of these regions. We will consider the two regions E and F_1 together because in some respects they are similar in detail. At night the ionization of the E-region is low. The F_1-region appears only after the sun has risen. After sunrise the ionization increases rapidly, reaching a maximum toward noon and decreasing thereafter toward evening. Then in general during the day the number of ions in these regions is proportional to the amount of sunlight upon them.

Let us observe the change of these regions with season. The number of ions is lower in the winter than in the summer. This is true in both hemispheres, so that when the highest numbers of ions are observed at noon in one hemisphere—as during June at Washington—lower numbers are observed in the opposite hemisphere—as at the same time at Watheroo. From this we see that at all times of the year the ion-density of these two lower regions during the day is in general proportional to the sunlight incident upon them.

A final and critical test is obtained by observations during an eclipse of the sun. In 1932 such an eclipse occurred in North America, being about 90 per cent total at Washington. It is fortunate that for these observations the eclipse need not be total, nor does obscuration of the sun by clouds interfere with the measurements in the least. This eclipse permitted a direct determination of the force active in ionizing these regions. It was found that, as the sun's disk was obscured, the ionization immediately decreased, again increasing as the sun came into view. Because only sunlight can have such an immediate effect, we can conclude that it must be the major source of the ionization of the two lower regions during the daytime.

It is not difficult to ascertain which portion of the sun's light is active in ionizing these regions of the outer atmosphere. We know that the sun radiates light of different wave-lengths, or we may say different frequencies, since wave-length and frequency are directly related. Now the amount of sunlight which we should observe for each frequency if the sun is a perfect radiator can be readily calculated for any assumed temperature.

The frequency of the radiation determines the color of the light; for example, a light-frequency of 8×10^{16} cycles per second, which is a short way of saying 80 thousand million million cycles per second, appears as a violet, while a lower light-frequency such as 5×10^{16} cycles per second appears as a red color. While higher and lower frequencies than these are invisible to the eye, they may be present and their intensity may be measured. Thus the invisible rays having frequencies above 8×10^{16} cycles per second are known as ultra-violet. The calculated curve then tells us how much energy we should expect to receive from the sun on each frequency.

The amount actually received at the earth's surface has been measured by various observers and is shown by the dotted curve (Fig. 7). These curves match quite well, except in the far ultraviolet. The observed radiation from the sun falls rapidly to zero at a light-frequency of about 10×10^{16} cycles per second, and none of the higher frequency radiation which we should expect is actually observed at the earth's surface. We conclude, therefore, that the difference between the observed and calculated curves must be energy which has been absorbed in the earth's outer atmosphere. A part of this energy is available for the ionization.

There is a fundamental law concerning light which can be written: $E = h\nu$. In this equation E is energy, h is a number known as Planck's constant, and ν is the light-frequency of which we have already spoken.

This is a law of quantum-physics which states that the energy in a photon of light is proportional to its frequency. Then the higher the frequency, the greater the energy involved in a fundamental quantum of light. The far ultra-violet light is of very high frequency, as we have seen, and the photons of such light involve very high energies When such a photon of high energy reacts on a molecule, it not only can separate it into its constituent atoms but it can also ionize these atoms by ejecting an electron. This is the process which is now believed to occur in the ionization of the outer atmosphere of the earth by the far ultra-violet light of the sun.

THE "ANOMALOUS" REGION

We have yet to deal with the F_2-region, this outer "bulge" which appears only

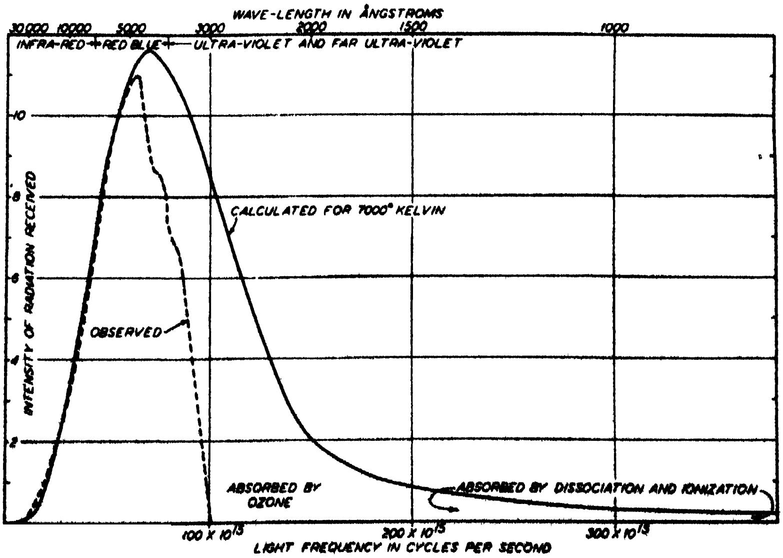


FIG. 7. ABSORPTION OF SOLAR RADIATION IN THE UPPER ATMOSPHERE FROM COMPARISON OF CALCULATED AND OBSERVED RADIATION ON VARIOUS FREQUENCIES.

when the sun is high overhead. This region does not behave in the same manner as the lower regions. It is found that violent fluctuations in ionization are common within a space of a few hours, while there are radical differences from one day to another. The trend of change in ion-density during the day is quite different in June and in December, and there are marked dissimilarities in this trend at each of the observing stations, which are widely separated over the earth. This region might be called the "anomalous" region. There are, however, a few features which are common to all stations. For one thing, the changes must be of solar region, as the changes, whatever they may be, occur with a period of the solar day.

When the average of the maximum ion-densities for this region are taken during the daylight hours, in contrast to the lower regions, the highest values occur at all stations at the same time of the year. For example, during June and July, the average ion-density at noon is lower at Washington, Huancayo and Watheroo than the corresponding average taken during December and January. It is a curious fact that the highest ion-densities should occur at all three stations during the same time of the year, in spite of the fact that they are in different hemispheres.

The earth travels an elliptical orbit and approaches nearest the sun early in January, being farthest away early in July. One might suppose that solar radiation of some sort, incident on the earth, should be greater during January than during July. The difficulty, however, is this: While the change in solar radiation received on the earth due to the ellipticity of its orbit is only a few per cent., the observed ratio of ion-density between July and January may be as much as 2 or 3 or even 4 to 1 in some years. A lack of continuity of observation limits the deductions which can be drawn from the limited data at hand.

During the solar eclipse of August, 1932, in North America, observers agree that in contrast to the sudden changes in ionization observed in the lower regions, only a slight decrease occurred in this upper or F_2-region. This observation checks with those made by observers in Russia and Japan during the solar eclipse of June, 1936. However, when observations were being made in North America during the solar eclipse of February, 1935, a very material change of ionization of this upper region occurred.

Here, then, are apparently conflicting data, although, because of the accuracy of the methods used, the reality of the conclusions in each case can not be doubted. However, this conflict gives some clue as to what may be occurring in this outer region. On investigating the dates on which these observations were made, it was found that the upper or F_2-region exhibited an eclipse-effect only when it was merged with the lower F_1-region. No distinct eclipse-effect was observed, however, when they were widely separated. These considerations lead directly to the view that the force which is ionizing the upper region does not undergo any change at the time of the solar eclipse.

In this line of reasoning it must be remembered that it is based upon only a few eclipse-observations in one hemisphere and that any conclusions must be open to question until checked by further eclipse-observations. If an ionizing agent from the sun is not eclipsed at the time of the optical eclipse, it can not be traveling at the velocity of light. This suggests that the ionization of this upper region may be due to particles which are shot off from the sun and which, upon colliding with the molecules of the earth's outer atmosphere, knock off electrons, thus creating the ionization which is observed. Such a hypothesis then proposes the bombardment of the outer atmosphere of the earth by particles from the sun. Such a hypothesis implies certain other conse-

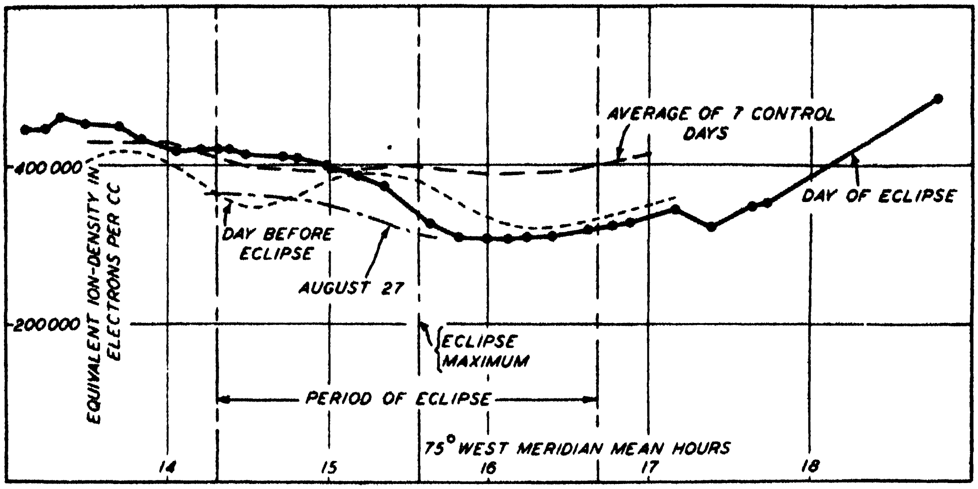


Fig. 8. Solar-eclipse effect in F_2-region on August 31, 1932, Kensington, Maryland.

quences which must be carefully verified by experiment before it can finally be accepted as fact. The necessary checks require (1) a continuity of data which is only now becoming possible with the new automatic equipment and (2) further eclipse-observations which are quantitatively exact.

Effect of Ultra-Violet Light

The main points discussed concerning the electrical state of the outer atmosphere are these. There are three main regions of ionization at heights of about 65, 130 and 180 miles, respectively. Of these, two exist above any location and at any time, as far as we know. The third and upper region appears separately only when the sun is high overhead, merging into the next lower region when the altitude of the sun is low. As these two regions merge, the resultant region takes on most of the characteristics of the more highly ionized upper region which has contributed to it. The major source of ionization in the two lower regions during daylight is the ultra-violet light of the sun. We tentatively suppose the ionization of the upper region to be caused by bombardment of the outer atmosphere by particles emanating from the sun. When the two upper regions are merged to form the single F-region, both sources appear active in producing its ionization.

That two regions should exist which both owe their ionization to the same source—ultra-violet light—presents another problem. A good many suggestions concerning this have been made. The most reasonable at the present time is based upon the composition of the atmosphere itself at these great heights.

Physicists have shown that if we conceive the outer atmosphere to be undisturbed, the lighter gases will rise to higher levels than the heavier gases. At the level of the earth winds are common so that the gas here is continually mixed and the proportion of oxygen and nitrogen remains always constant. At great heights, however, the lighter nitrogen should float to higher levels than the heavier oxygen. Then a ray of light entering the outer atmosphere will have passed a certain number of nitrogen atoms after penetrating through a certain amount of atmosphere. The same ray must penetrate much more deeply into the atmosphere to pass the same number of oxygen atoms. Oxygen is most effective in absorbing certain light-frequencies, while nitrogen is most active in

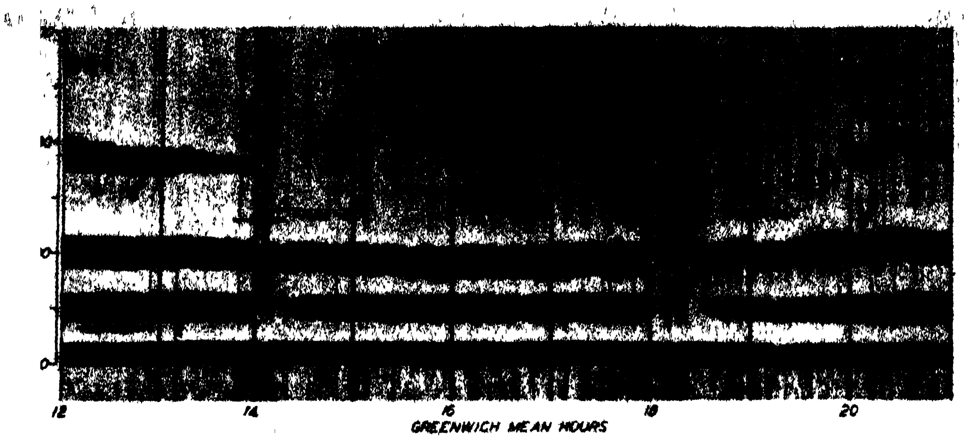


FIG. 9. EXAMPLE OF RADIO FADE-OUTS, HUANCAYO MAGNETIC OBSERVATORY, MAY 28, 1936.

absorbing others. The light which ionizes the nitrogen will be absorbed at a higher level than the light which ionizes the oxygen. Therefore, two distinct levels of ionization would exist, each because of the absorption of a different band of light by a different gas. The difficulty with such an explanation is that as yet we can not be sure whether such a partial separation of gases by diffusion actually occurs in the upper atmosphere and whether the atomic states which have been assumed in this example are actually correct.

FLUCTUATIONS IN IONIZATION

As we have seen, it is impossible to observe the very high-frequency radiation from the sun because of its absorption in the upper atmosphere. Some of the characteristics of this radiation can be determined, however, from its reaction on the outer atmosphere. The mean value of ionization is changing from year to year in an orderly manner. We see that so far this change has followed the change in sunspot-activity. In the two lower regions an increase of ionization of about 45 per cent. has occurred since the last sunspot-minimum. From observation in the visible spectrum, the change in the visible radiation during this period appears almost negligible. This suggests that there is much more change in the ultra-violet radiation, which causes this ionization, than in the visible radiation as the solar activity varies, a conclusion which has important consequences in the study of the sun.

When we examine the change of ionization of the third and highest region of the ionosphere since the last sunspot-minimum, we find the change is not 45 per cent. but more than 250 per cent. This not only emphasizes a difference in character of the ionizing forces as already suggested, but implies, on the basis of our hypothesis of particle-bombardment, an enormous change in the number or velocity of particles emitted from the sun as solar activity varies. With regard to these deductions, however, it must be remembered that as yet our observations are available for only about six or seven years and definite conclusions must await operation over a longer period. Nevertheless, deductions from the shorter period are not entirely speculative when we remember the close relationship between sunspot-activity and terrestrial magnetism and, in turn, the dependence of the earth's magnetic phenomena upon the ionosphere.

It will be realized that the changes

which are taking place in these regions must have immediate effects in radio transmission and in the earth's magnetic field which depend upon them. For example, a few years ago certain police radio stations were assigned to a frequency of about 43 megacycles per second because then this frequency was high enough to penetrate the ionosphere. Therefore, the range of these stations was limited to their immediate vicinity.

To-day, as the result of the enormous increase of ion-density in the F_2-region, these stations are frequently heard in Europe. Thus, to provide the best service with the minimum of interference to other services, suitable allocation of stations to proper frequencies depends upon a knowledge of the fluctuations of ionization in the upper atmosphere. The best frequency for transmission across the Atlantic this year may not be the best next year, and a quite different one may be desirable.

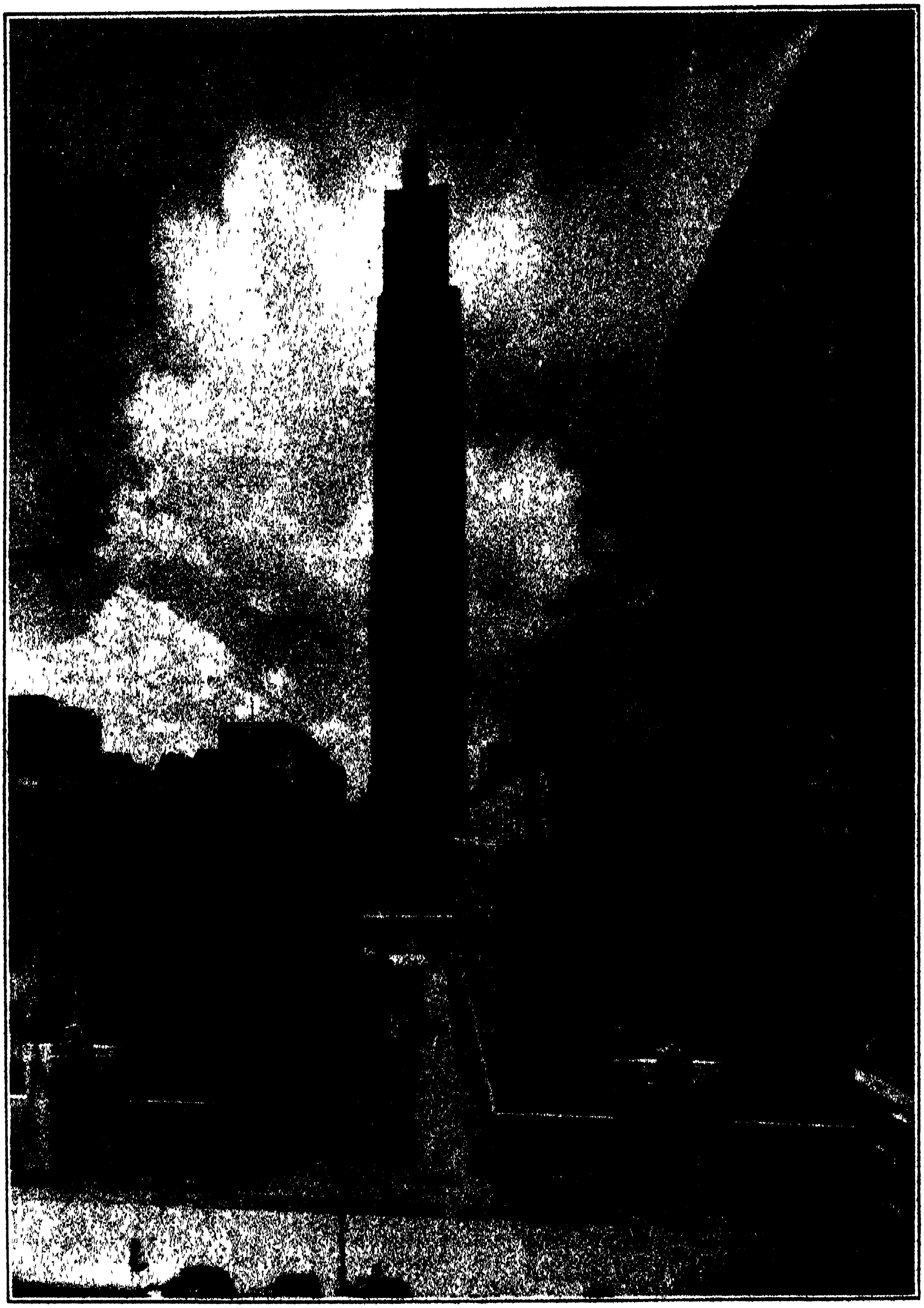
At the beginning of this paper we mentioned cases of coincidence of a brilliant solar eruption with certain geophysical effects. Suppose we examine in a little more detail what has happened in the ionosphere during such an occurrence (Fig. 9). At the beginning of the eruption all reflections faded out suddenly, staying out for its duration. When echoes again appeared, the upper regions were essentially the same as they were before the eruption. This demonstrates that the upper two regions were not affected, but that the region below 100 kilometers was so strongly ionized that it completely absorbed the radio waves without reflecting them.

The importance of this localization has been recently emphasized by my colleague, A. G. McNish, who has pointed out that the character of the disturbance accompanying the solar eruption is intimately associated with the normal diurnal variation of the earth's magnetic field. Such information adds to the accumulating evidence which must eventually determine in which ionized region magnetic fluctuations find their source. Likewise the change of ionization in the lower regions with the years has a definite relation to changes in the activity of the earth's magnetic field.

IMPORTANT EFFECTS UNMENTIONED

In presenting this picture of our present knowledge of the electrical state of the earth's outer atmosphere, I have been limited necessarily to a description of some of the basic facts so far uncovered. In assessing these it has been necessary to pass over a multitude of observed effects, each of which contribute definite facts to aid in the construction of the theory. There are, for instance, the sudden sporadic ionizations of very great intensity at the 100-kilometer level. These can occur at any time of the day or night; they are found more frequently during the summer months in any location; they occur more frequently toward the polar regions, practically never occurring at the magnetic equator. During such times the upper regions may be entirely invisible to the exploring radio wave because of the great intensity of this ionization, and phenomenal radio transmissions on ultra-high frequences occur. It has also been necessary to leave the night effects entirely unmentioned.

We see, then, that this outer atmosphere of the earth, once believed isolated and inaccessible, is now yielding to exploration by attack with modern experimental tools. Effects of the first rank, which might otherwise have passed unnoticed, have been discovered through observations at widely separated stations. Despite the relative vacuum in the outer reaches of the atmosphere, the events which occur there play a definite and important part in the scheme of things. In learning the facts concerning these regions, we increase our comprehension of the events taking place around about us.



ROCKEFELLER CENTER, LOOKING WEST.

THE MUSEUM OF SCIENCE AND INDUSTRY IS LOCATED ON THE FIRST FLOOR OF THE TALLEST BUILDING.

THE LAYMAN WANTS TO KNOW

By ROBERT P. SHAW
ACTING DIRECTOR OF THE NEW YORK MUSEUM OF SCIENCE AND INDUSTRY
and MARION CLYDE McCARROLL

WHAT, in science, interests the layman? That, in brief, is the question to which the New York Museum of Science and Industry has been seeking a definite answer in the twelve years since a bequest in the will of Henry R. Towne started it on its way.

For the museum was created specifically for the average person, as a place where the mysteries of science would be made plain to him in simple visual demonstrations; where he could acquire at least an elementary working understanding of the terms on which he is able to live and work and play in a universe run by inexorable scientific laws.

When the museum's move from its previous location in the Daily News Building to more commodious quarters in Rockefeller Center was consummated it undertook to give the public a chance to speak for itself. At certain times throughout the day and evening—and the museum is open to the public every day in the year from ten in the morning until ten at night—members of the museum staff strolled about the place and entered into casual conversation with visitors, with the idea of discovering what brought them into the museum and what their particular interests were in the varied exhibition about them.

The results of this strolling questionnaire have served to confirm many of the conclusions at which museum officials have been gradually arriving throughout the past twelve years of their experience. It has been established first of all that the answer to the question with which this article opened is as simple as it is comprehensive and *vice versa*. One single word covers the whole matter. What, in science, interests the layman? Everything.

Out of something over three thousand persons questioned within one month, there has emerged a composite layman who, like Kipling's famous elephant's child, has an "insatiable curiosity" about the mechanics of the world in which he finds himself. There is nothing about which his lively imagination does not play, no stone of knowledge which he is willing to leave unturned, lest something of vital interest or significance should escape him. There are, naturally enough, some things that intrigue him more than others, and hence it is only logical that of these three thousand people, a little more than a third should have come to see an exhibit in some specific field. But the range of these special interests covers so wide a territory that, after the most careful survey, it is found only to give added emphasis to that comprehensive "everything" which expresses what the public is interested in on the scientific side of life.

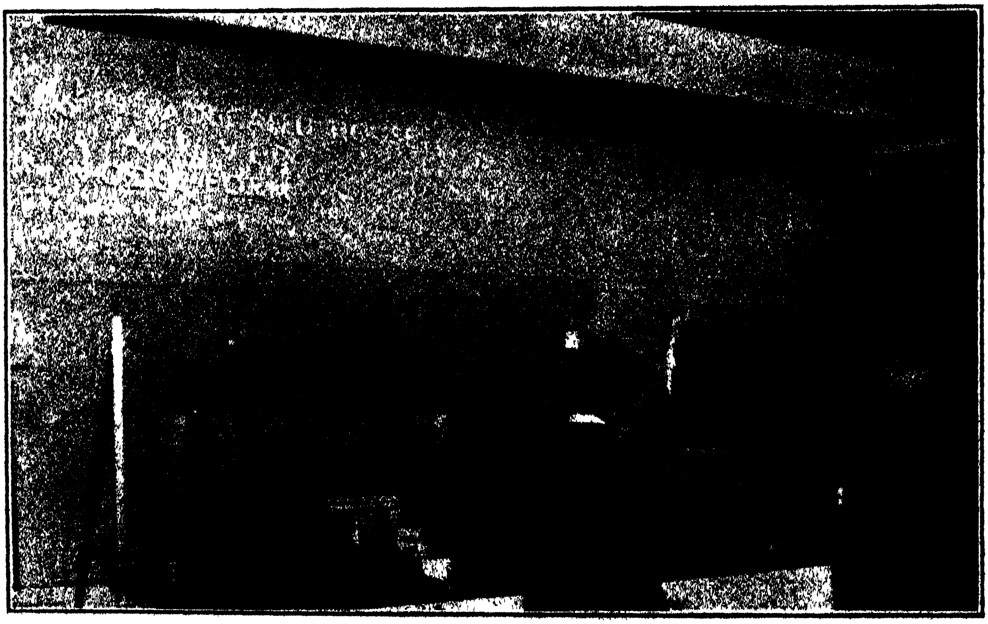
Furthermore, there are four main things this composite average person wants to know about matters scientific; four questions that he asks, to which the museum exhibits must supply the answers. These are: "What is new in science?", "What is its history?", "How does it work?" and "What does it mean to me?" In other words, the novelty, the background or development, the operating mechanics and the practical application of scientific achievement must all be supplied in order to give the layman the picture he wants.

With this background, then, of defined public sentiment added to twelve years of what might be called the experimental method of scientific presentation to the layman, the Museum of Science and Industry is evolving a considered policy which seeks to approach the matter from the main indicated angles. It is doing this by means of a threefold program as follows: First, through permanent exhibits which serve as background in basic fields; second, in special temporary exhibits of a news character, which show some striking scientific achievement for the first time or present a comprehensive view in compact form of scientific development along one particular line; and third, through various demonstrations in which the scientific side of some practical everyday matter is presented by a lecturer using a graphically dramatized operating exhibit by way of illustration.

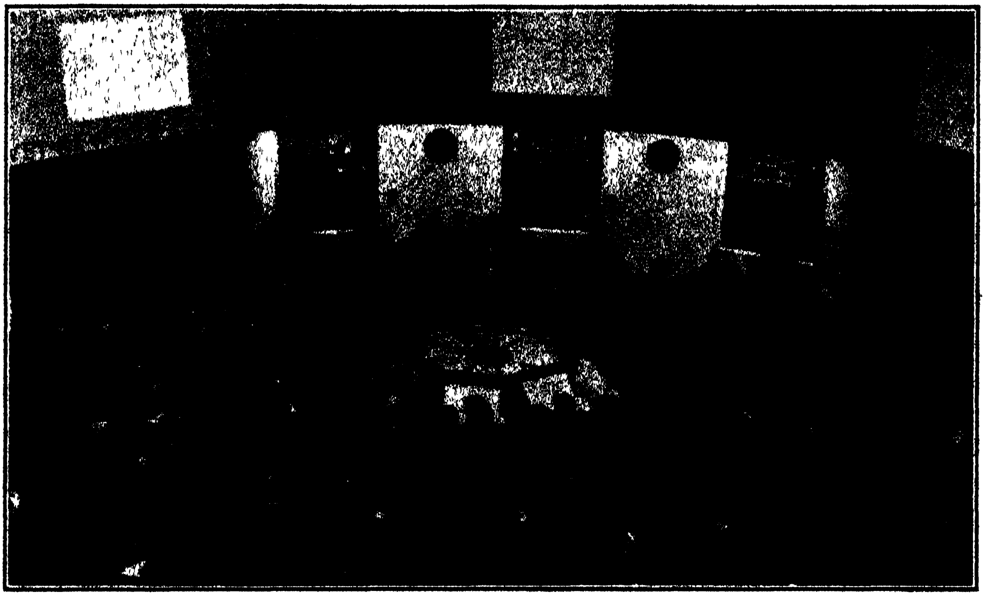
One other thing has been a guiding principle in the minds of those who have worked out the present program of the museum. That is, that scientific principles can be most readily grasped by the lay mind where they can be seen actually at work and that if an exhibit can be operated by the individual himself it is most practically valuable of all.

So, wherever possible, exhibits have been arranged so that they can be set in motion by the simple pressure of a button by the visitor himself, giving him not only the pleasure of being an active participant in the scientific scene, instead of a passive onlooker, but also the opportunity of showing himself any particular demonstration as many times as he chooses. As one young enthusiast put it: "If I don't understand it the first time, I can do it over again for myself until I do, without having to ask anybody to show me and have them think I was dumb."

As its permanent background, then, the museum has a series of eight main divisions embracing variously the fields of housing, textiles, food, communications, transportation, machinery, power and electrical science and technology. In



THE BUILDING OF MODEL HOUSES.



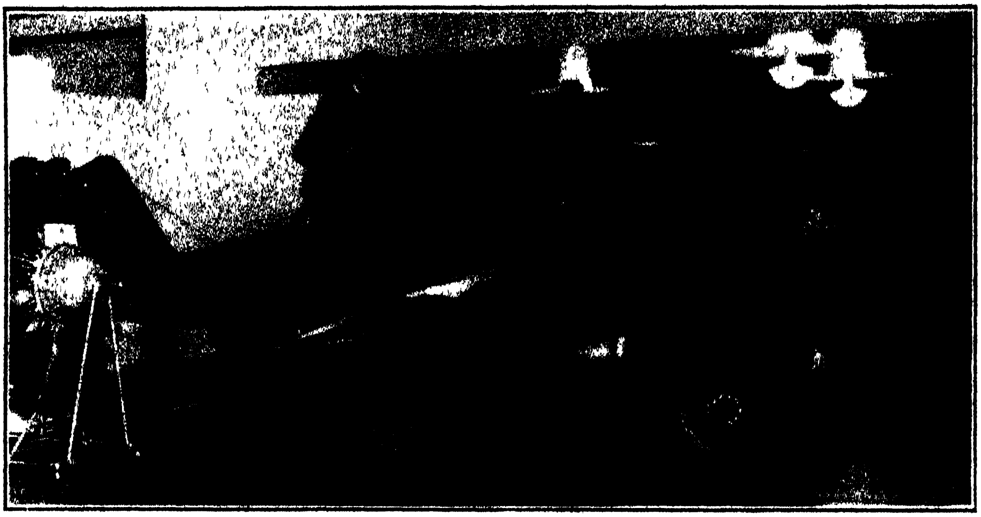
THE TRANSPARENT WOMAN

AN ELECTRIC SYSTEM ILLUMINATES EACH ORGAN IN ROTATION AS THE LECTURER EXPLAINS ITS FUNCTION.

each of these, it purposes to show chronological scientific development from early times to the present, and against them are presented, from time to time, in special exhibit and dramatized demonstration, those significant achievements which have raised man from ignorant savage to informed and cultured world citizen, from primitive fear of natural forces to intelligent understanding and control of them, and his way of living from crudest discomfort to the last refinement of efficiency and ease.

In the housing division, the visitor may study the historical sequence of mankind's ideas of shelter, from the first crude dwellings made from tree branches and leaves to the glass and chromium steel of the ultra-modernist. Supplemented by current special exhibits, the housing section as it stands at the moment presents a pageant of human living from the angle of the historian, the builder, the architect, the city planner, the economist, the interior decorator and the home owner.

On the historical side, there are two exhibits: One, a series of small models showing typical dwellings in different parts of the world from that of the lake dweller to the modern suburban resident, and the other, an elaborate presentation of American housing, beginning with an Indian long house and carrying through successive periods to the present era of compact city apartment and comfortable country residence. A separate exhibit comprises a number of model houses designed by outstanding modern architects, whose chief business is the planning of skyscrapers, while still another of the units of this comprehensive housing panorama offers eight miniature rooms, built and decorated by an interior decorator in period style, true down to the last detail of tiny chair or objet d'art. In a side room just off the housing section, an exhibit of unique models pre-



THE DEMONSTRATION AIRPLANE IN THE AVIATION DIVISION.

pared by WPA workers shows the problems which housing experts have faced, solved and are still wrestling with in American cities.

In the textile field, full-sized models and actual working machines demonstrate the development of spinning and weaving, showing the manufacture of rayon, together with a continuous moving picture, and demonstrating the manufacture of rare and expensive specialty fabrics derived from animals inhabiting the mountainous regions of South America, Tibet and other countries.

The food section offers, against a historical background of plowing methods, demonstrations of such modern processes as sugar refining, milling, mechanical refrigeration in industry and in the home, milk pasteurization and the like. A special exhibit was a model explaining the government's soil conservation program, consisting of a representative stretch of farming country, with sections marked off to illustrate the particular method applied to each type of land, whether pasture, woodland or field.

The history of communication from sign language to radio, with various working instruments which the visitor may operate at will, is told in the communications division. A favorite instructive plaything in this part of the museum is the dial telephone, set beside a working model of a central station, which, as one dials a number, goes into action and shows just what happens during the process of making a telephone call. Another prime favorite is the model of the prow of a ship with a tiny wireless antenna, which may be maneuvered by means of a knob to pick up signals sent out by miniature lighthouses flashing in the distance.

The transportation division, consisting of four sections devoted respectively to highway, railroad, marine and air travel, covers the story of historical development in these important departments, largely in colorful scale models of horse-drawn vehicles, ships, locomotives and airplanes, many of them springing into action when a button is touched. A genuine life-sized covered wagon in the highway transportation section, and, in the marine section, a large ship model which may be raised and lowered in drydock, are two exhibits which particularly intrigue visitors.

Just how appealing the subject of aviation is to the amateur has been demonstrated at the museum in the widespread interest aroused by the placing on exhibition of a Taylor Cub plane, the most popular type of plane for amateur flying. At intervals during the hours when the museum was open to the public, a young and enthusiastic lecturer stood by the plane and talked informally on "Why an Airplane Flies" In accordance with its regular practice of announcing the various demonstrations, the talk was heralded over the museum's loudspeaker system just before it began, and the rush for the corner where the plane stood, as well as the size of the crowd which assembled to hear the talk, both gave ample witness to the fact that this was one of the most popular features of the museum program.

In the machine division, original machines and replicas, both historical and modern, demonstrate the speed and efficiency with which things are done in the mechanical world to-day. Striking a note that touches the casual visitor even more closely, a special exhibit of machines used in the business world is shown, and the passer-by may stop and experiment as much as he pleases with electrical machines that count and add and sort and tabulate and write far more casually and accurately than any human.

Then there is the power division, where numerous types of engines, turbines, models and dioramas trace the steps that have been taken through the years in harnessing water, steam and electricity for the benefit of man. Most of these may be put through their paces by means of push buttons or lever.

The principles of electrical science and technology, abstruse as they are to the average person, become intelligible to the lay mind when they are explained in terms of pulling magnets, jumping balls and various kinds of apparatus that revolve and leap and twist and turn. A host of such things, demonstrating such mysteries as terrestrial magnetism, alternating and direct current and many

A LECTURER DEMONSTRATING MINIATURE HYDRO-ELECTRIC POWER PLANT.

AN EXHIBIT IN THE ELECTRO-TECHNOLOGY DIVISION

others, are permanent exhibits in the museum's electro-technology section, while the current attraction of a temporary character is the smallest hydro-electric power plant in the world, generating electricity right out in the open for all to see. Hydro-electrical unit, transmission lines, sub-stations, a miniature railroad and two toy-sized industrial plants that run by the power generated, tell the story in simple, vivid form, and several times a day a lecturer is on hand to put the whole thing in motion and explain it in popular terms.

In addition to those already mentioned, the museum recently held four major exhibitions and demonstrations which have aroused wide interest. Of these, the now nationally famous "transparent woman" probably attracted the most attention, for the simple reason that it is the first of its kind in the world, and was shown at the museum for the first time anywhere. Built on a human skeleton and enclosed in a transparent "skin" of a substance known as cellhorn, every organ of the female body is shown, together with the circulatory system. By an ingenious electrical system, each organ is illuminated in rotation as a lecturer points it out and explains its function, giving to many among the audience their first really scientific conception of how the human body is actually constructed.

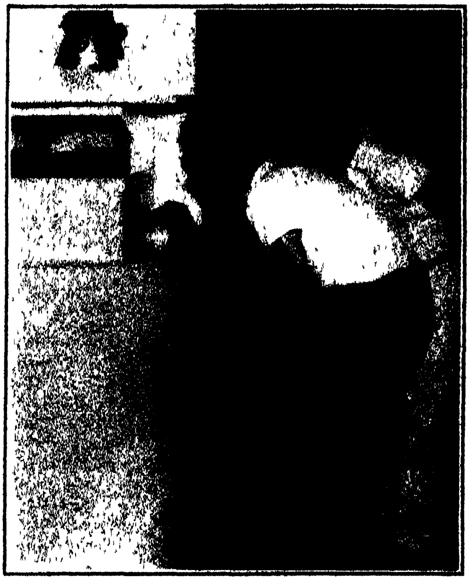
Also receiving notable popular attention was the fire prevention exhibit, in which the eight most common fire hazards were demonstrated and explained by the extremely dramatic method of starting a certain conflagration or causing an explosion in miniature form under perfectly controlled conditions Electrical fires, so-called dust explosions, fires caused by vaporous chemicals and spontaneous ignition fires were all illustrated in spectacular manner, accompanied by a running talk which told why this happens when that is done, and how to avoid it.

The Edison Industries Exhibition, in which the major achievements of the great inventor are shown in historical models, original machines, replicas, dioramas and many other forms, together with exhibits representative of the numerous important industries which have grown out of Edison's original work, has been at the museum for almost a year. The attention which the public has paid to this feature indicates clearly that there is an abiding interest in the type of exhibit which shows a great man and his work.

The invention of Polaroid, a material which puts the polarization of light under practical control and makes it an understandable and usable tool in everyday life, has been called by no less a person than Dr. R. W. Wood, of the Johns Hopkins University, the most significant invention in the field of optics within the past generation. The story of Polaroid, together with demonstrations of its numerous practical applications, was given to the public for the first time in a series of exhibits showing such exciting things as non-glare headlights, three-dimensional motion pictures in natural colors, new achievements in amateur and professional photography and microscopy, and glasses that, by the control of light glare, reveal to the wearer hitherto hidden beauties of color and effect both outdoors and in. A lecture-demonstration given at intervals made it possible to view with clearer understanding and greater enjoyment the different phases of the subject presented in the various exhibits

In January, the popular automobile driving clinic, which drew thousands of people to the museum throughout the past spring and summer, returned for another period. During its previous stay, an average of 150 people a day—the capacity use of the equipment—were tested for color blindness, for the quickness of their reaction in braking a car; for their susceptibility to headlight glare; for their ability at the steering wheel in holding the car to the proper driving lane on the highway and for their skill in judging the relative speeds of moving vehicles.

As the schedule of lectures, demonstrations and special exhibits is now arranged, it is not unusual for visitors to remain in the museum for the best part of an entire day, in order that nothing may be missed. Nor do any seem to find the minutes dragging as they wait for the beginning of some special feature. On the contrary, they do well if they manage to see all that there is to be seen during the intervals between the demonstrations.



THE ZOETROPE
A MODEL OF THE TOY WHICH LED EDISON TO THE INVENTION OF MOVING PICTURES.

In the first ten months after the Museum of Science and Industry opened its headquarters in Rockefeller Center, nearly half a million people viewed its exhibits, with the attendance mark moving steadily upward, ample evidence that here, scientifically speaking, is the answer to what the layman wants to know.

CONSERVATION AND USE OF FORESTS IN THE SOUTHWEST

By G. A. PEARSON

SENIOR SILVICULTURIST, SOUTHWESTERN FOREST AND RANGE EXPERIMENT STATION,[1] U. S. FOREST SERVICE

EXTENSIVE land conservation in the United States had its origin in forestry more than 40 years ago. Through the forestry profession, the doctrine of land management was transplanted to this country from Europe, where for centuries forests, including timber, soil, water and wild life, have been managed for continuous production. The first national forests, or forest reserves, as they were then called, were withdrawn from the public domain in 1891. In 1897 Congress authorized the President to provide for the regulated utilization of reserved forest lands. It was not until several years later that effective forestry practice began to take form. During the administration of President Theodore Roosevelt, the "forest reserves" were renamed "national forests" and their area was greatly extended. By 1934 the national-forest area in the United States, including Alaska and Puerto Rico, had grown to 162 million acres, nearly one eighth of which was in Arizona and New Mexico. Besides the high forests or saw timber, this domain includes large areas of low-growing woodland species and areas occupied by brush and grass. Only forests of the first-named class are discussed in this paper, because it is here that management has made most progress and promises the greatest returns.

THE TIMBERLANDS OF ARIZONA AND NEW MEXICO

Of the nearly 11 million acres classed as saw-timber land in Arizona and New Mexico, 86 per cent is in public ownership. National forests contain 66 per cent., Indian reservations 17 per cent., national parks and state lands account for about 3 per cent. and 14 per cent. is in private ownership.

Destructive agencies have dealt less harshly with the forests in the Southwest than in most other regions. Vast areas of pine, fir and spruce remain in essentially their primeval state (Fig. 1). About one fifth of the commercial saw-timber lands have been logged, but a large portion of this cutting has taken place under more or less conservative methods. Fires that burned whole mountain sides in the early days are almost a thing of the past, and most of the old burns are gradually restocking under protection. Although examples of devastation by cutting and fire are not lacking, it is estimated that less than 10 per cent. of the timberlands have suffered to the extent that planting is necessary to reforest them. Timberlands as a class are not a wasted resource calling for expensive rehabilitation. Exceptions to the rule are almost invariably lands which have not had the benefit of forest management. A better picture would be presented to-day if the early pioneers had been more forestry minded; but, on the other hand, what would the picture be if forest management had been postponed until the present time?

FORESTRY A PUBLIC FUNCTION

Timber-growing as a commercial enterprise generally has little appeal to private capital in the Southwest because of the long time required to realize returns on such an investment. Individual owners prefer or are forced by financial circumstances to convert marketable timber into cash as quickly as possible without regard for permanent production. Quite commonly, the first cutting on private lands leaves enough immature trees to preserve some semblance of a forest but, at most, the remnants will be spared only a few decades. Under the pressure of taxes and interest, the individual owner usually has no other choice. When timber exploitation is complete the land more than likely becomes a liability to both the owner and the public. The only practical solution is acquisition by public agencies before devastation goes beyond control. Federal and state governments are able to forego immediate income for sustained returns and, besides, public interest takes into account important indirect values such as water, recreation and wildlife which rarely bring a financial return to the individual owner.

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[1] Maintained at Tucson, Arizona, by the Forest Service, U. S. Department of Agriculture, in cooperation with the University of Arizona.

A growing public appreciation of esthetic qualities in forests often assumes expression in a protest against commercial cutting. The forester's answer is that beauty and utility can be combined to the advantage of both. Actually, Arizona and New Mexico have thousands if not millions of acres of timber which, on account of location or topography, probably can never be economically logged. Under public ownership, such forests will be managed as watersheds or recreational areas, or with the purpose of restoring and preserving primeval conditions. But as long as timber is needed for human use, accessible forests will be called upon to supply that need.

TIMBER MANAGEMENT IN THE NATIONAL FORESTS

Effective timber management under public ownership is exemplified in the national forests. The administrative policy of the Forest Service has recognized from the outset that forestry involves not only conservation but also utilization. A lumber industry and a livestock industry, both dependent upon the national forests, furnish a livelihood in whole or in part to thousands of people. If at times exploitation has appeared to profit at the expense of conservation, human and social aspects have usually stood in the background. In the cut-

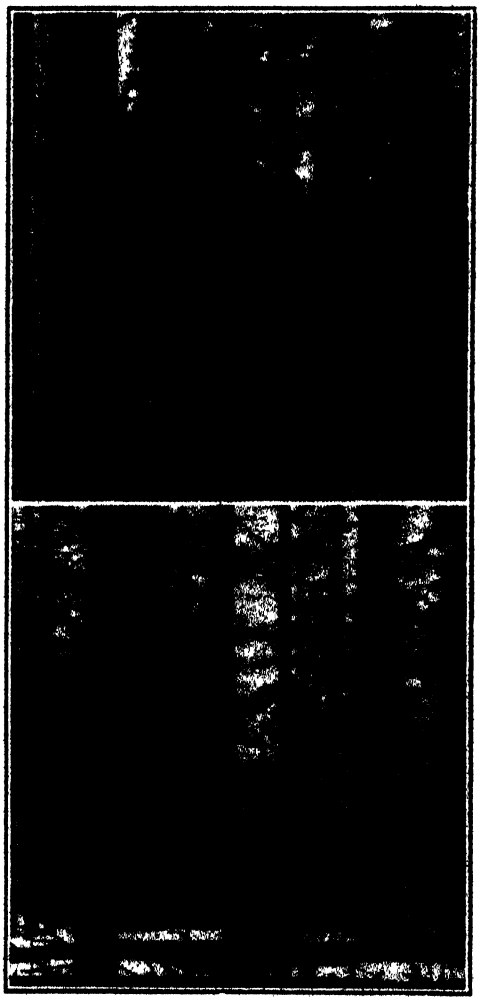


FIG. 1. VAST AREAS OF PINE, SPRUCE AND FIR

REMAIN IN ESSENTIALLY THEIR PRIMEVAL STATE. (UPPER) PONDEROSA PINE (*Pinus ponderosa*) AND (LOWER) ENGELMANN SPRUCE (*Picea engelmanni*) AND CORKBARK FIR (*Abies arizonica*). COCONINO NATIONAL FOREST, ARIZONA.

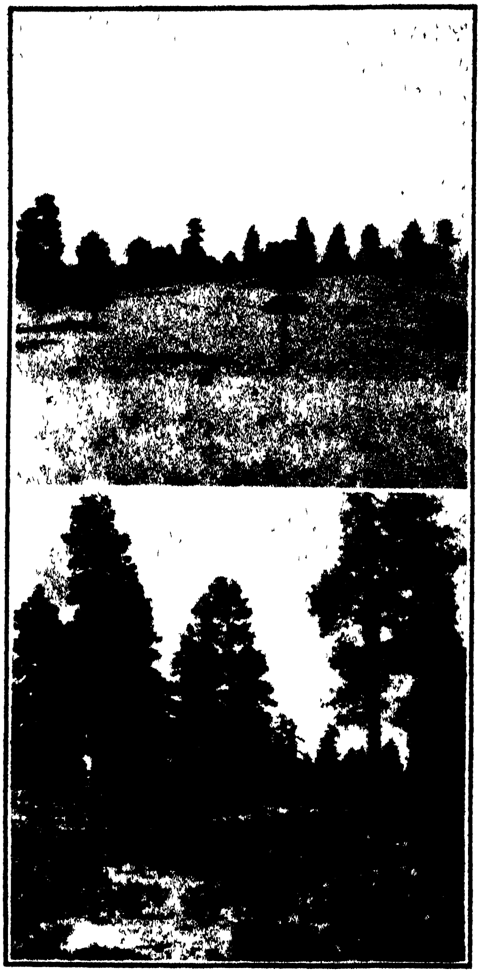


FIG. 2. CUTOVER PINE FORESTS

(UPPER) UNREGULATED CUTTING ABOUT 50 YEARS AGO, FOLLOWED BY FIRE AND IMPROPER GRAZING, RESULTED IN POOR NATURAL REGENERATION AND TIMBER GROWTH. (LOWER) NATIONAL FOREST CUTTING 27 YEARS OLD; NATURAL RESTOCKING IS ALMOST COMPLETE AND THE TREES LEFT UNCUT ARE GROWING AT A RATE THAT WILL PROVIDE A SECOND HARVEST EQUAL TO THE FIRST ABOUT 30 YEARS HENCE.

ting of national-forest timber in Arizona and New Mexico, no concessions have been made that would seriously jeopardize regeneration and continuous production of the forest. If the reader's observations seem to contradict this statement, account should be taken of the fact that extensive areas within the national forests were cut, or private timber rights acquired before the lands were incorporated in the national forests. Conspicuous examples are the land grants of alternate sections ceded to the railroads before the national forests were created, the timber sold to lumbermen and the land itself reverting to the government after logging by private interests. Control of grazing has been more difficult and generally less effective than control of timber cutting on national-forest lands, but substantial progress in decreasing damage to the forests by live stock has been made during the last decade.

Essential steps in timber management are protection, orderly harvesting, restocking and improvement of young stands.

Protection: Protection implies, first and last, security against fire. The pine forests of the Southwest are less subject to crown fires than are the dense forests of the Pacific Coast and the Northwest; but a ground fire once in 20 years may destroy all young trees and thus prevent restocking. Fires in tall grass or in logging "slash" (the debris left after cutting), are especially destructive. Fifteen years ago, slash fires of a thousand acres or more were all too common, but now they seldom attain a fourth that size. Marked improvement in fire protection has resulted from development of transportation and communication systems, including roads, motor equipment and telephone lines. No less important has been the progress in methods of fire detection and in the training of fire-fighting personnel, which have gone steadily forward over a quarter century. It must be expected, however, that as increased production makes available greater quantities of fuel in the form of young trees, leaf litter and grass, fires will become increasingly difficult to control.

Certain biological agencies may cause

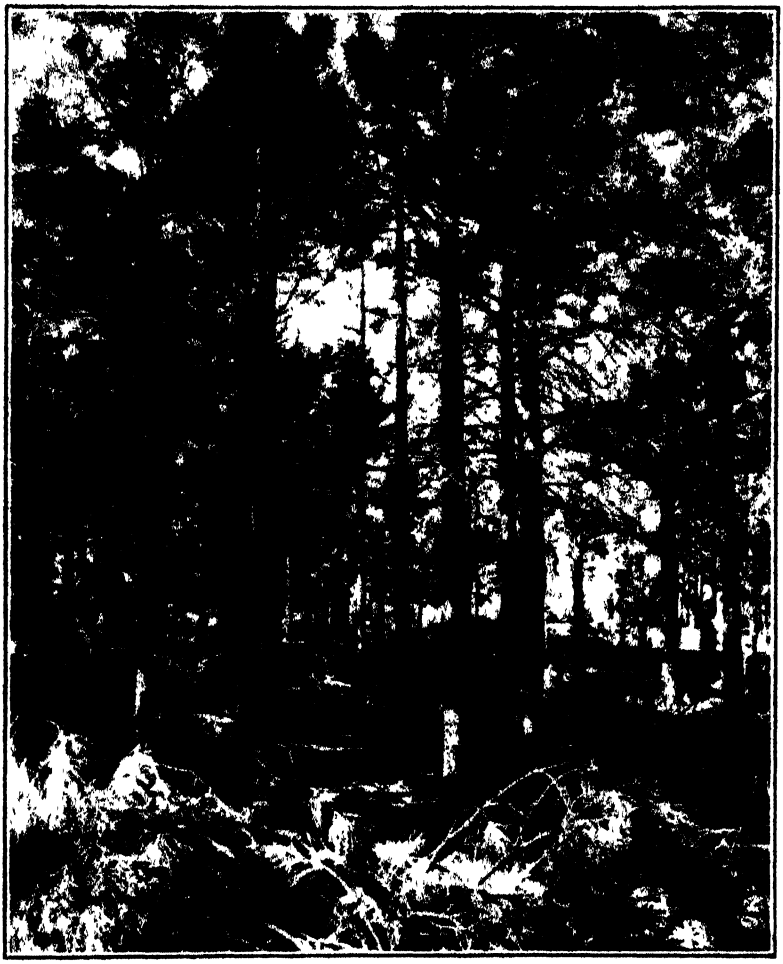


FIG. 3. "TIMBER STAND IMPROVEMENT"

IN THE COCONINO NATIONAL FOREST. THRIFTY TREES OF DESIRABLE FORM ARE FREED OF COMPETITION BY REMOVING INFERIOR NEIGHBORS, AND THE TRUNKS ARE PRUNED OF LIMBS TO A HEIGHT OF ABOUT 17 FEET IN ORDER TO PRODUCE LUMBER FREE OF KNOTS. ONE OF THESE FAVORED TREES IS INDICATED BY A WHITE CROSS. BRANCHES ARE SCATTERED IN THE LARGER OPEN SPACES IN ORDER TO PROTECT THE SOIL.

damage that calls for special protective measures. Domestic live stock browse tree seedlings; porcupines kill seedlings and damage trees of all ages by gnawing the bark; bark beetles may destroy entire stands, and fungus diseases may kill the stems and foliage or cause decay of the wood. At the present time several CCC camps are employed in an effort to stamp out a new pine disease known as "twig blight."

Orderly Harvesting: One of the oldest principles in forestry is the sustained yield. The term is self-explanatory: it means that cutting is so regulated that over a long period it will not exceed the rate of growth, and that production will be sustained or increased as the years go by. Thus far, the rate of cutting in the national forests of the Southwest has been less than the rate of growth. This can not be said of all classes of ownership, but if good forestry is henceforth practiced on all the forest lands they are capable of supplying the raw material for a much enlarged lumber industry. Overcutting, even if good fortune should bring about natural regeneration, results in deferring the next harvest by anywhere from 100 to 200 years; conservative cutting, on the other hand, permits successive harvests at intervals of 60 years or less (Fig. 2).

To regulate cutting on a plan of sustained yield requires information which in this region has taken many years to acquire. The forests of the Southwest usually contain several generations or age-classes, ranging from mature veterans down to the sapling stage. Records of some 50,000 trees of different ages and sizes on typical areas in different localities over a period of 20 or more years have determined the rate of growth and mortality. Yield tables are being prepared from which the size of the timber crop can be predicted far into the future with greater accuracy than the Department of Agriculture estimates currently the annual crops of corn, wheat and cotton.

Natural Restocking: The most vital process in timber management is regeneration or the replacement of trees which have been harvested or have died from other causes. For the most part, this must be accomplished by natural means —by natural seedfall virtually entrusted to the elements. During many years after the national forests were created, natural restocking failed to follow cutting on the largest logging projects in the Southwest. Rigid fire protection and provision for natural dissemination of seed proved to be without avail. The Southwest became known in forestry circles as a region where forests are doomed to decline through failure of regeneration. Lacking knowledge as to what actually took place, it became convenient to place the blame on the climate. Research discovered that the major trouble lay in grazing, and later it was found through extensive practice that an effective remedy is available in control of numbers of stock and seasons of grazing rather than in total exclusion. A further discovery is that grazing under a forester's direction can be employed to aid tree reproduction by control of competing vegetation. Many facts have been gathered on the relation between seed production, climate, soil, plant competition and the reproduction of pine. Nature is kind indeed if she permits 5 per cent of the seeds which mature to germinate and grow to the sapling stage; and yet, this order is not unusual because nature is wasteful. Despite a multitude of adverse agencies, many tree seedlings usually gain a foothold in the course of two or three decades. For the purpose of this discussion it is sufficient to say that, so far as regeneration of ponderosa pine is concerned, the climate is really more favorable in the Southwest than in most other regions where this species occurs, and that if man will take advantage of factors within his control, timber crops can be harvested with reasonable assurance that the forests will remain a perpetual source of public wealth.

Care of Young Stands: Recent efforts have turned toward improving the yield of timber crops in the national forests. Not only can the annual rate of volume growth be increased, but the quality of wood products can be improved. Lumber, like meat, fruit and other commodities, is sold according to grade. It is estimated that our forests can be made to yield three or four times their present monetary returns by growing more and better trees per acre. During the last three years, advantage has been taken of employment relief measures by subjecting thousands of acres to "timber stand improvement," which consists essentially in removing inferior trees and encouraging the growth of desirable ones

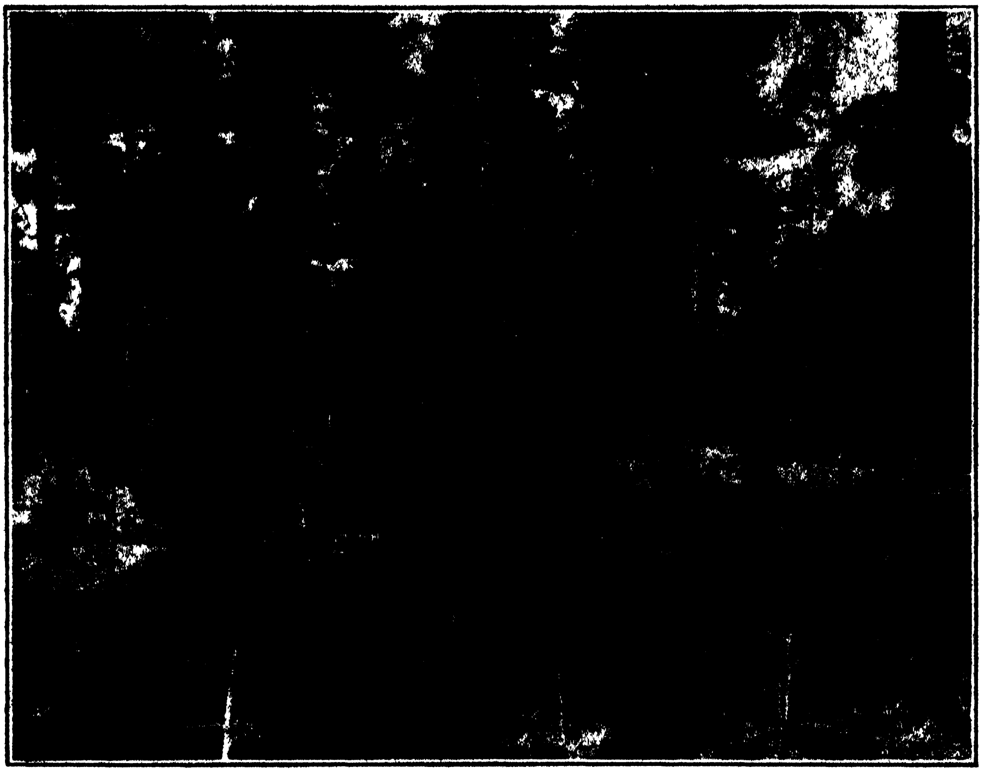


FIG. 4. AN OLD PINE FOREST

IN WHICH THE LARGER SPACES BETWEEN TREE GROUPS ARE OCCUPIED BY SEEDLINGS AND SAPLINGS, OR "ADVANCE REPRODUCTION." WHEN SUCH A FOREST IS LOGGED UNDER ADEQUATE SAFEGUARDS, THE REMAINING YOUNG TREES RESPOND VIGOROUSLY TO THE STIMULUS OF INCREASED SUNLIGHT AND SOIL MOISTURE. THE LARGE TREE IN THE MIDDLE FOREGROUND IS DEAD.

by thinning and pruning (Fig. 3). Of the various classes of work adapted to employment of the Civilian Conservation Corps, few hold promise of self-liquidation in the same measure as timber stand improvement.

Economic Aspects of Land Conservation

It is axiomatic that whatever is conserved should be worth conserving. The Southwest contains vast areas whose capacity for growing crops of any kind will always be low. The submarginal land problem is not confined to farm lands, but may apply as well to forest and range. Nor can expensive rehabilitation measures always be justified by indirect values such as water and recreation. Water for domestic use is a priceless asset, but irrigation has economic limitations that must be recognized. In thinly populated regions there is also a limit to the acreage that can be maintained at public expense primarily in the interest of recreation. The time will come when public lands must not only cease to impose a tax burden but must become a source of revenue to the nation.

Of the various types of "wild" land in the Southwest, forests offer perhaps the greatest possibilities of economic self-support. A relatively small percentage of the commercial timber area has lost its productive capacity. In public hands, timber is capable of yielding a much

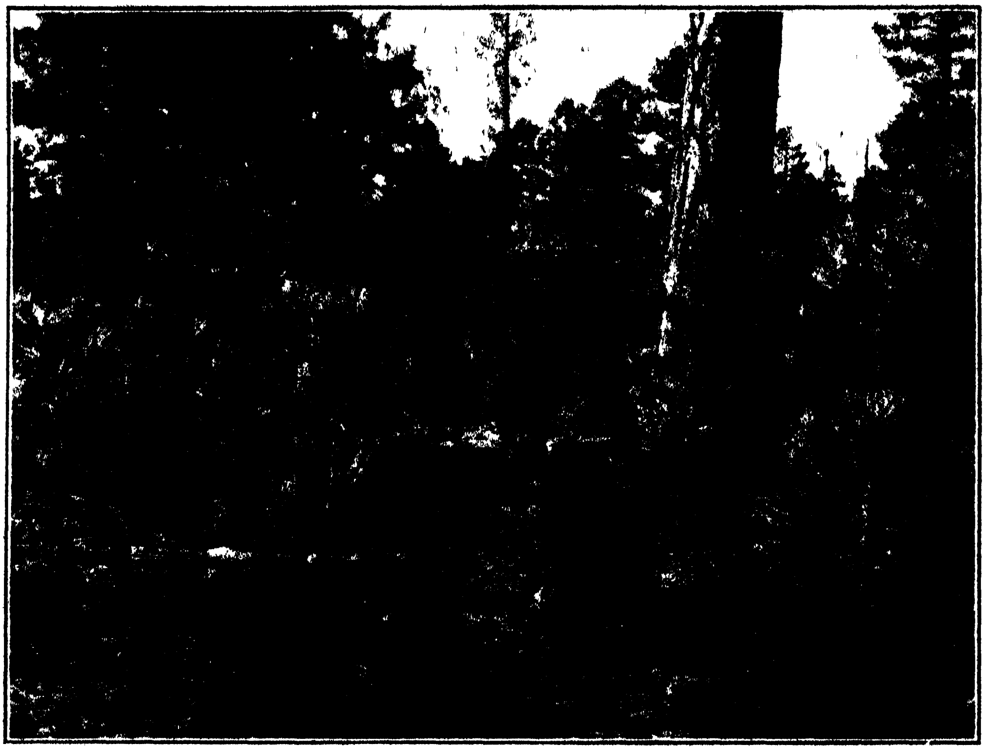


FIG. 5. A MANY-AGED PINE FOREST

MADE UP OF VETERANS OVER 200 YEARS OLD, YOUNGER GROUPS OF MERCHANTABLE SIZE ABOUT 150 YEARS OLD, STILL YOUNGER GROUPS OF ABOUT 100 YEARS, "POLE" GROUPS OF 50 TO 60 YEARS, SAPLING GROUPS OF 1914 AND 1919 ORIGIN, AND FINALLY SEEDLINGS OF 1928 GERMINATION. IN THE NEXT CUTTING NEARLY ALL THE VETERANS AND A FEW OF THE 150-YEAR CLASS WILL BE REMOVED, LEAVING AN ABUNDANCE OF YOUNGER TREES TO MAINTAIN THE FOREST CANOPY AND PROVIDE FUTURE CROPS. FORT VALLEY EXPERIMENTAL FOREST, U. S. FOREST SERVICE.

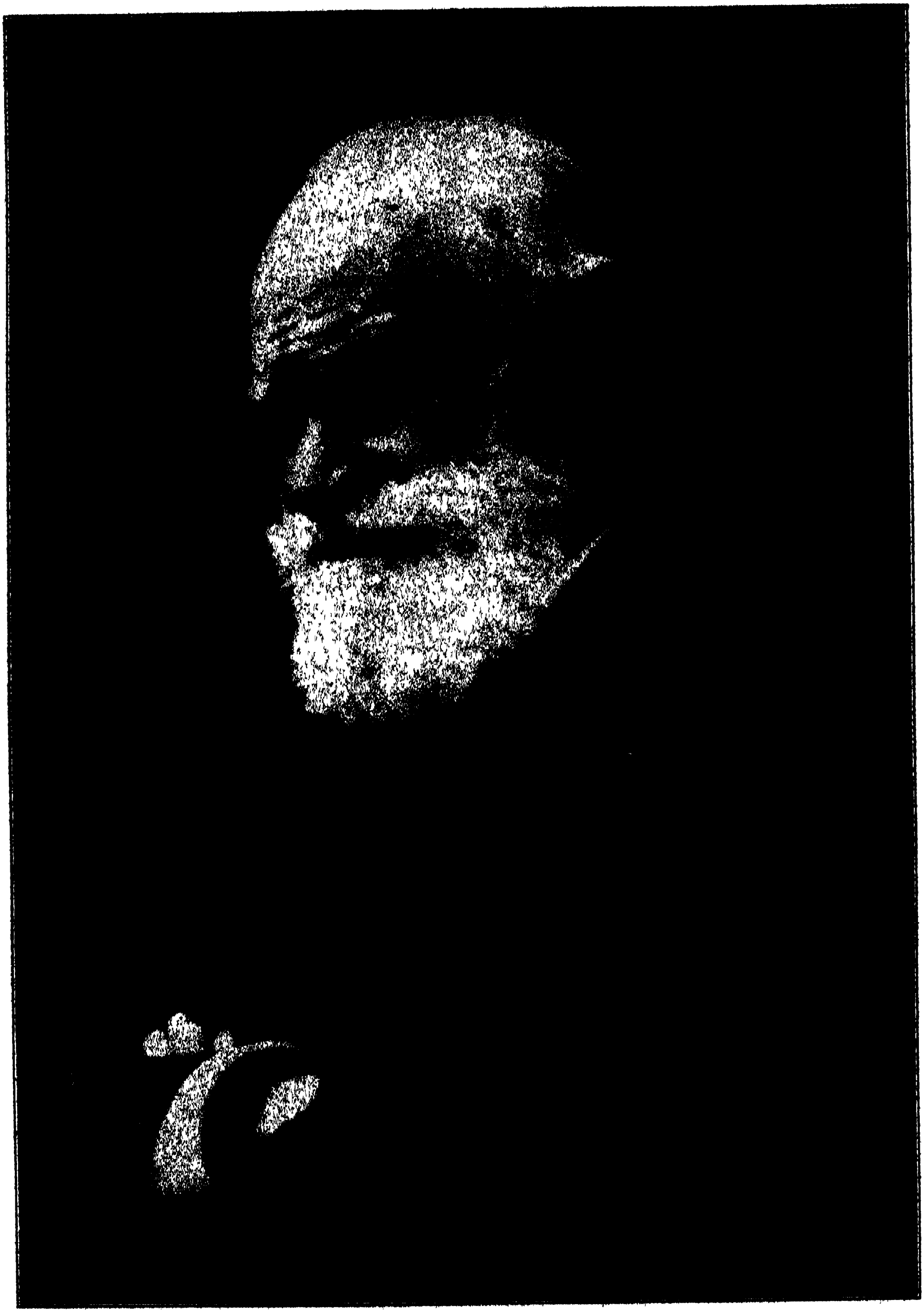
higher monetary return than most other uncultivated crops. This is true whether the comparison applies to direct sale of the raw materials or to public benefits in the form of employment and local business incident to conversion of raw materials into usable products.

The high watershed values ascribed to forests need not suffer from cutting under good timber management. From the pine mesas to alpine heights the forests of the Southwest occupy the zones of heaviest precipitation, especially snowfall, that contributes most to sustained stream-flow. A forester's conception of an ideal watershed is a forest whose canopy is open enough to admit a high proportion of the precipitation, but dense enough to form a continuous carpet of leaf litter. In such a forest the soil is more porous and permeable to water than either grassland or cultivated fields. The best if not the largest contribution of a forest to water supplies is by percolation through underground channels. Under the type of timber management which is now in process of development, the presence of many age-classes will make it possible to remove mature timber without exposing much of the soil area, and thus the watershed functions will be met as fully under regulated cutting as in the virgin forest (Figs. 4 and 5).

Under advanced forms of management the harvesting of timber crops does not permanently mar the beauty of the forests. True, logging operations do leave quantities of unsightly debris, but this largely disappears in 15 or 20 years, or becomes screened by young trees. A condition which contributes to heavy cutting and the volume of debris is a preponderance of old and defective trees. Timber management is gradually converting over-mature forests into stands in which the younger generations predominate. When this transition has been brought about, logging scars will be less conspicuous and more quickly healed than at present. The public may well demand that forests be kept beautiful; but, on the other hand, it must recognize that the removal of mature trees is in accord with nature's scheme to preserve the biological vitality of the forest and that utilization of the mature crop provides revenue with which to meet the cost of protection and administration.

Forests of the Future

Conversion of untended or unwisely exploited forests into a high type of managed forest is a slow process Thirty years of organized forest management in the Southwest has made a substantial beginning, but only that. Noteworthy progress has been achieved in natural regeneration, which is the first requirement, regardless of the object of management. Accomplishments in this direction are by no means complete. Other steps are in the direction of higher quality production. But not all forests will be managed for maximum timber crops; in fact, extensive areas probably will never hear the sound of the woodsman's saw and axe. For the most part recreational areas will be in locations from which logs can not be economically transported, and why not, now that automobile roads have made the most remote forest sections accessible to pleasure seekers and nature lovers? Forests managed primarily for timber production will be none the less valuable for other legitimate uses, subject to the doctrine of greatest good to the greatest numbers. The principles of sustained yield and selective cutting automatically avoid the extremes of uniformly old or young stands, and instead will foster a gradual transition toward many-aged forests in which trees of all ages, ranging from mature veterans to tender seedlings, intermingle in groupwise arrangement.



IVAN PETROVICH PAVLOV

THE GREAT TEACHER AND MASTER OF SCIENCE

IN MEMORY OF PROFESSOR IVAN PETROVICH PAVLOV

By Professor L. A. ANDREYEV
ALL-UNION INSTITUTE OF EXPERIMENTAL MEDICINE, MOSCOW, USSR.

PROFESSOR I. P. PAVLOV was a rare combination of genius and research worker, of an exceptionally talented experimenter and great teacher. Possessing a lively intelligent mind, a passionate striving towards knowledge, a strong will and unusual steadfastness in pursuing his aims, Pavlov was endowed by nature with gifts which, in conjunction with his constant effort for self-improvement and his untiring labor, became the source of his creative energy, great ideas and his immortal fame. For more than sixty years he was a tireless and fearless searcher for truth.

During this long period of work marked by singleness of aim and constant striving for the confirmation of new ideas, tormenting doubts and the joys of achievement, those characteristics were crystallized in Pavlov which are inherent in a great investigator who creates a new epoch in the history of science.

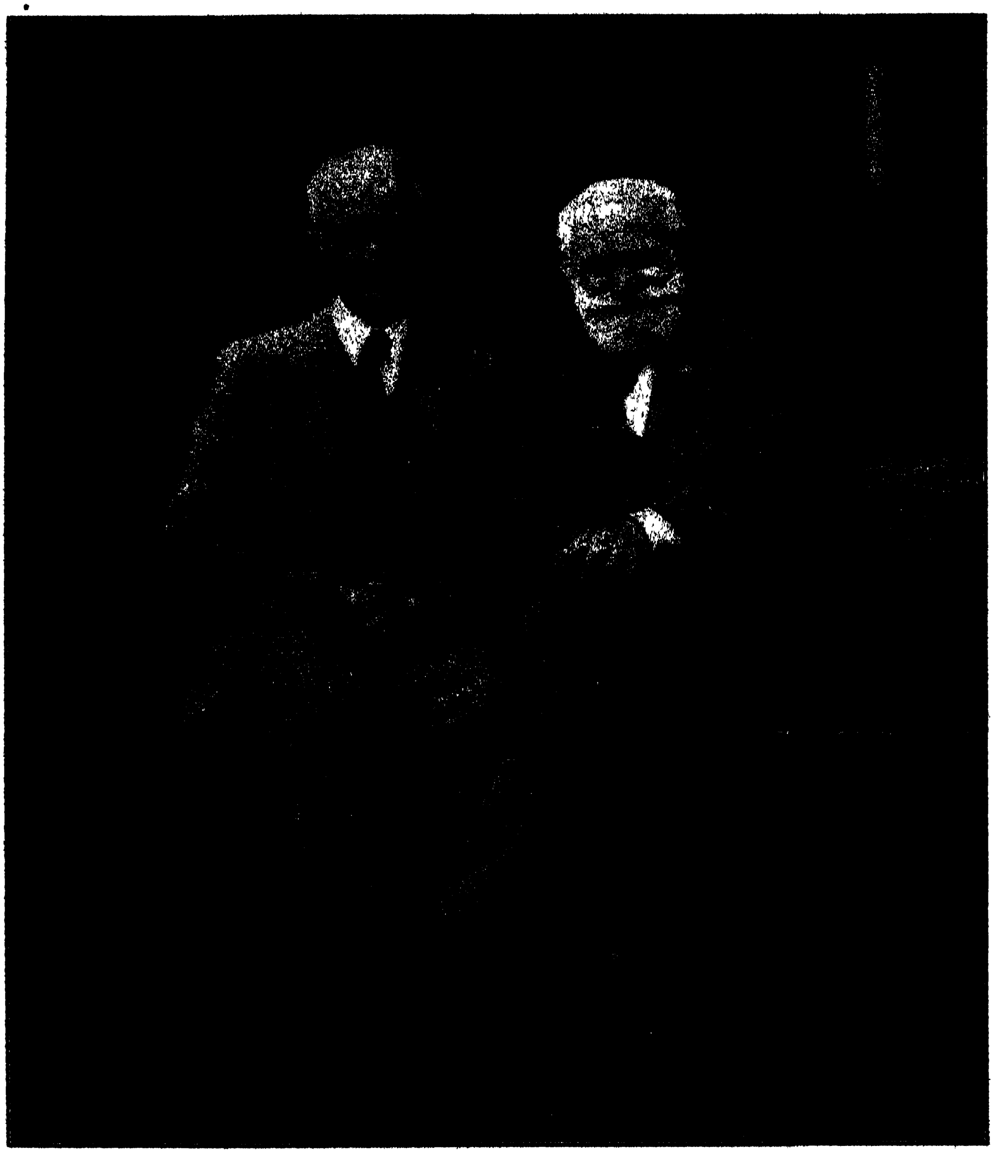
Therefore, while studying the exceedingly rich scientific heritage left by Pavlov, it is necessary to study, at the same time, his manner of scientific work and his personality as a research worker and teacher.

The author of this essay does not take it upon himself to give a complete analysis of Pavlov's genius and his methods of work. Such an analysis would require many years devoted to the most thoroughgoing study from this point of view of all Pavlov's work; it would be necessary to follow step by step the history of the birth of his great discoveries and ideas, to reveal the entire process which helped to shape his personality against a wide social background. This will be the task of future investigators. The present essay is only the first experiment in this direction—an attempt to present the living image of Pavlov as a master of science and a great teacher. The material on which this essay is based are the impressions and experience accumulated by the author during fifteen years of acquaintance and work with Pavlov. In dealing with Pavlov's unified nature it is difficult to divide the teacher from the truth seeker, the manner of passing on knowledge from the manner of accumulating it. It is quite inevitable that in exposition the boundary between these two characteristics will be practically indiscernible.

"STUDY, COMPARE AND ACCUMULATE FACTS"

Pavlov acquired his knowledge not from books but from the fountain-head of life: in the laboratory, in nature's own factory, by sitting at the pedestal of facts.

In 1873 he crossed the threshold of Zion's laboratory for the first time and from then until the very end of his life he never ceased experimenting. The laboratory was not only his workshop but also his great school. Pavlov attached great importance to facts in scientific investigation. "Study, compare and accumulate facts. As perfect as is the structure of a bird's wing, the bird would never be able to fly if its wings were not supported by air. Facts are the air of the scientist; without them you would never be able to fly. Without them your theories are useless efforts,"—thus wrote



PAVLOV AT THE AGE OF EIGHTY YEARS WITH DR. HARVEY CUSHING.
THE PHOTOGRAPH WAS TAKEN ON THE CAMPUS OF HARVARD MEDICAL SCHOOL IN 1929 AT THE XIITH INTERNATIONAL PHYSIOLOGICAL CONGRESS.

Pavlov in his last letter to the Soviet youth who have dedicated themselves to science. This he always repeated to his laboratory students.

But a fact gains force and significance only when it is accurately described and checked. In that case the fact is indisputable and controls the investigator. Woe to the investigator if he ignores those facts which do not fit into the frame of his conception or destroy an *a priori* theory. A fact contains within itself forces which act in contradiction to each other: it is constructive and at the same time destructive. This is a *primum mobile* on which progress towards truth depends. Discoveries are born precisely there, where facts which form exceptions to the rules are investigated. These deviations from the usual order demand special study.

However, the mere accumulation of facts without a general idea in mind, without a plan, is a useless occupation. Pavlov taught: ". . . try not to stop only at the surface of a fact. Don't become an archive of facts. Try to penetrate the secret of their appearance. Obstinately seek the laws governing them." The aim toward which facts are accumulated is precisely this last point—"the discovery of the laws governing facts." Thus a fact is not an end in itself, but only the means towards mastery of the general laws of nature.

How should facts be accumulated? "When you have no ideas you can't see the facts," Pavlov often reiterated when his attention, during an experiment, was fixed by some important phenomenon which repeatedly cropped up and was evident to the eye for a long period of time but nevertheless remained unnoticed. New facts, new phenomena must be illuminated by ideas which correlate them. Only under such conditions can investigative thoughts really bear fruit.

"OBSERVATION, OBSERVATION AND OBSERVATION"

However, in order to observe new facts it is necessary to know how to observe them. Pavlov attached primary importance to keenness of observation as the main ability required by an experimenter. Upon his suggestion the main building of the biological station in Koltushy has inscribed on it the simple words: "Observation and observation." Pavlov himself possessed this quality to perfection; in him it was habitual. In the most difficult moments of an investigation, when the data obtained by an experimenter did not lend themselves to analysis, Pavlov himself took up the experiment. And almost always the puzzling phenomena were explained. If the matter proved more complicated, supplementary experiments were performed; new collaborators were drawn into the investigation. Pavlov stubbornly persisted until he found the cause of this new phenomenon. Very often new ideas and themes were engendered in this process. Pavlov always recalled: "The very best themes, the most profound questions were conceived during an experiment, while working." Observational keenness helped Pavlov to conquer a considerable difficulty which he encountered while still in the period of the study of the physiology of digestion. This incident is so instructive that I give it in Pavlov's own words.[1] Due to the corrosive action of the pancreatic juice, it was impossible to obtain a chronic fistula in the pancreas.

> One of the dogs operated on by our method began, some ten to fifteen days after the operation, to be affected by the corrosive action of the juice. Our methods did not completely attain the end sought. The dog was kept chained in the laboratory. It so happened that one morning, to our sorrow, a heap of plaster broken from the wall was found near the dog, which usually was very quiet. The dog, still chained, was moved to another part of the room. The following morning the same story had been repeated! Again the wall had been ruined. At the same time it was noticed that the dog's abdomen was dry and that the inflammation of the skin had diminished. Only then we finally guessed what was the matter. When we made the dog a bed

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[1] I. P. Pavlov, "Lecture on the Function of the Chief Digestive Glands." Third edition (Russian), p. 18, 1924.

> of sand, the animal ceased scratching at the wall and slumber no longer harmed him. We (Dr. Kuvshinsky and I) gratefully recognized that by its intelligence the animal helped not only itself but also us.

This remarkable incident impressed Pavlov so profoundly that he immortalized it on the bas-relief of the pedestal of a monument to the "unknown dog," set up in front of the laboratory.

Pavlov often used himself as an object of observation—especially when, during an illness, his usual activity was naturally restricted. In 1927, in the seventy-eighth year of his life, he underwent a serious operation for the removal of gall-stones. A few months after the operation symptoms of palpitation of the heart appeared. For a time Pavlov analyzed in detail the cause of these cardiac disorders. Special experiments on Pavlov were performed jointly with M. K. Petrova, until, finally, the explanation was found, and recorded by M. K. Petrova in "Post-operative Cardiac Neurosis, Partly Analyzed by the Patient-physiologist I. P. P. Himself," which was published in 1930.

The most characteristic instance of Pavlov's observational keenness is related to his study of the changes brought about in his own organism by increasing age. In connection with the study of the lability and inertia of the nervous processes with which his laboratory was then (1933) engaged, Pavlov often spoke during laboratory discussions of the changes caused by age in the higher nervous activity, and in illustration related the results of his observations upon himself.

> You see, although age can not be considered pleasant—it brings many shortcomings with it—still, I want to draw some benefit from it. And obviously, in connection with conditioned reflexes and the study of the nervous system, I constantly watch what age is bringing me. It is interesting that the same thing is happening to me that happens to all old men. That is natural. And you know that one of the first effects of age is loss of memory regarding impressions which were recently fresh.

Then the physiological explanation follows: ". . . age is first of all expressed in the weakening of the reactions of the cortex of the cerebral hemisphere. . . ." It is possible to cite a great number of incidents showing that no matter in what surroundings or conditions Pavlov found himself, the experimenter and observer in him was always evident. A keen observation became second nature to him. Even a few hours before his death Pavlov watched with alarm the work of his own brain. And when he felt that he was beginning to lose control over his thoughts, he asked for a neuropathologist in order to analyze with him the nature of the disorders of his brain. The neuropathologist gave Pavlov a satisfactory explanation and then he felt reassured, fell asleep and, a few hours later, died.

Pavlov was strict towards himself and strictly demanded of his students correct accumulation of facts.

"THE A. B. C.'S OF SCIENCE"

Facts must be correlated, inspired by a unified idea. Where does this idea come from? Confused thinking only leads to unnecessary, wordy webs. Scientific research demands sequence first of all—consistency in the accumulation of knowledge. "Learn the a. b. c.'s of science before ascending its heights. Never reach for the next step before having mastered the preceding one." Such was Pavlov's counsel to the youth striving towards scientific activity. In this respect Pavlov himself was the best example. Gifted by nature with many weapons for mastering and directing her, Pavlov armed himself, in addition, with knowledge which he acquired by stubborn and persistent work. Thus armed he became a person dangerous to nature.

Without the acquisition of positive knowledge scientific work is impossible. As stated above, Pavlov learned, not so much from books, as directly in the laboratory. This was not a passive contemplation of natural phenomena passing before the eyes of the experimenter, but active observation accompanied by intense thinking. The experiment was strictly planned in all its details and was subordinated to the aims of the experimenter. Nothing escaped the vigilance of Pavlov. Always tense and concentrated on his work during an experiment, he resembled a hunter tracking his game.

"A physiological experiment," said Pavlov, "may depend upon a mass of petty conditions and unexpected occurrences which should be noticed during the experiment, otherwise our material loses its real purport."

Pavlov had illustrious teachers, who were outstanding physiologists—Zion, Ludwig, Heidenhain. They were founders of a new division of physiology. However, Pavlov's studies were not limited to the laboratories of the best physiologists of his time. He also studied in the clinics, working as the director of a laboratory in the clinic of the renowned Botkin for several years. Here Pavlov was faced with the task of finding solutions to new questions raised by practical physiology. Working intensely from morning until late at night, Pavlov mastered new problems, elaborated new methods and acquired new knowledge. In this work first arose the idea of the mutual benefit existing in an alliance between experimental methods and the clinic, the rôle of practical experience in the discovery of biological laws.

For five years Pavlov held the chair of pharmacology in the Military Medical Academy. In this period, Pavlov, being a reader in physiology, not only mastered a subject new to him but also breathed a stream of new life both into the method of pharmacological investigation and the teaching of pharmacology. Knowledge of pharmacology was of great service to him later when he applied it to the study of the higher nervous activity.

Pavlov had an excellent knowledge of the literature of his subject. A strict schedule for a working day included a special period set aside for the reading of magazines and books. He read slowly and re-read one and the same article or book two or three times. While reading he was often aggravated when he met a bare assertion or unverified fact. He argued and defended himself vehemently when his work was criticized. And, finally, he was overjoyed and triumphant if his facts were confirmed by other investigators.

Pavlov studied all his life. He was not afraid to begin from the a. b. c.'s. In 1918, when he was 69 years old, Pavlov, becoming interested in some mental disorders, went every Sunday to his friend Dr. Timofeyev to study at the Udelnaya Psychiatric Hospital. Many years later, when Pavlov was already eighty years old, he began to study psychology. Like a young student he started to study the classical text-books on psychology, read a great number of psychological articles and nevertheless, with all his erudition, modestly considered himself an empirical-psychologist.

Thus, for more than fifty years Pavlov constantly amassed more knowledge. This explains the boundless extent of his interests.

"COMPLEXITIES ARE CONQUERED BY SCIENCE ONLY GRADUALLY AND IN SEPARATE PARTS"

Even a tremendous store of knowledge and the accumulation of a great quantity of facts is still insufficient for true scientific creation—the birth of ideas. The investigator is ever confronted with the endless complexity of phenomena, their varied interactions and complex causal dependence. How should one separate into its component parts and analyze all this complexity? How can the dismembered parts be put together again?

Pavlov showed how science attacks this difficult problem. In 1902 standing on the threshold of an enormous uninvestigated field, embarking upon an objective physiological study of the work of the brain, he found himself invading the forbidden zone called "spiritual life," a zone which, until the advent of Pavlov, was wholly ruled by psychology. Pavlov clearly understood the danger of this audacious attempt. He knew that he would meet with desperate resistance on the part of both nature and man. "One should not," wrote Pavlov in 1906, "close one's eyes to the fact that the contact of true consistent natural science with the last border of life can not take place without important misunderstandings and opposition. . . ."

Thirty-four years have elapsed since then. The final aim—the full and complete mastery of all the natural laws regulating the function of the brain—is still remote, but the first battle has been conquered, the method has justified itself, the results offer assurance that the road selected is the right one.

"The complex can only be conquered by science by one part at a time and in sudden attacks, but gradually becomes more and more embraced by it." In this manner Pavlov encouraged those who stopped from indecision before the complexity of a phenomenon. To embrace all at once is impossible. One must limit oneself. One must be able to concentrate one's thoughts exclusively on a single problem. Pavlov revealed the unusual advantage of this method. For ten years he was engaged in the study of the physiology of digestion, devoting all his own energies and the energies of his coworkers to this investigation. All other problems not related to digestion were excluded from the laboratory. More than thirty years he devoted to the physiology of the brain, categorically resisting all distractions from the main problem. Persistent cogitation and a strained concentration of thoughts lasted for years. Pavlov knew how to cause his collaborators to think of the same thing with which he was busy. What an iron will is needed for this! How many temptations are met with on the road of an investigator! How difficult it is to restrain oneself, not to be turned aside, when directly within the process of investigation new unstudied fields are revealed, when new questions arise and new conceptions tempt the investigator with promising discoveries. Pavlov never lost himself in such He knew how to counteract temptations himself and how to keep his students from making mistakes. He mastered all subjects in their complete aspects with exceptional penetration and breadth, without dwelling on details. He always saw the final aim before him clearly. "Only when we keep in mind the whole—the normal operation of one or another branch of an organism—can we differentiate without difficulty the accidental from the essential, the artificial from the natural; only then we can easily find new facts and often notice mistakes quickly." This idea guided Pavlov when, from separate, odd analytical data, he elaborated the synthesis of digestion. The entire teaching on the higher nervous system grew from the simple fact of studying the salivary secretions, from the physiology of the salivary glands. The fact of the existence of salivary glands is in itself of small significance. The salivary glands are an organ whose biological importance in the system of an organism is paltry. However, this ability to seize upon basic factors, to note the leading links in a chain made it possible for Pavlov to open a new chapter in physiology—the chapter on the function of the brain. The difficulties met on the road of investigation were many. They were conquered, but sometimes temporary delays occurred, pauses for orientation, for gaining strength by means of verification of that which had already been achieved, for making new plans. Other difficulties were temporarily put aside. That which was postponed was never forgotten—it was retained in Pavlov's unusual memory for future solution in a new manner.

Dangers

Pavlov knew very well the dangers which confront an investigator in his work. He always told his students that it is better to recognize danger than to ignore it. And the first, most important danger lies in the experimenter himself: "Usual weakness in thinking processes: stereotyped ideas and the tendency to work with preconceived notions." Stereotyped and preconceived ideas bind the scientific mind, hinder the flight of scientific fantasy. Conventionality as a property of nervous activity was even made the subject of a special study in Pavlov's laboratory.

To break away from conventionality is a difficult task not only for dogs under the condition of laboratory surroundings, but also for a person. The stronger the conventionality, the more difficult it is to get rid of, and the more painful is the rebuilding. And in extreme cases such a breaking away from conventionality is accompanied by a nervous "break down," *i.e.*, by a pathological condition. Conventionality in scientific thought means routine, doctrinairism, deification of authorities, belief in the infallibility of old dogmas. Pavlov was able to demolish old dogmas, to introduce fresh, new and bold ideas into investigative work. His independent mind was subordinated only to facts and experience. Only the striving to learn from experience, not only from his own but from the experience of others made a person equal to his time.

Preconceived ideas are necessary for scientific investigation, but one must be able to reject them. Claude Bernard considered that the preconceived idea is a question addressed to nature. We must coolly listen to the answer, and then, having received it no matter what it may be, we must dismiss our question.

During the process of work many guesses and theories arise in the investigator's mind. A large number of them are annihilated by the criticism to which they are subject and only a very small number of suppositions and hopes are materialized. This cleansing work frees science from false views. Not many men possess the ability to confess their mistakes straightforwardly and honestly. How many times Pavlov, in conversations with his collaborators, admitted: "To err is not shameful. How many times have I been greatly mistaken! I confess it. If you think, you make mistakes. He who doesn't think, he never errs." The main characteristic of scientific thought is love of truth. The investigator learns to love truth in the laboratory where the results of an investigation may be correct or incorrect, where mistakes against the truth of nature are never forgiven. The ability to speak the truth was second nature to Pavlov. In the laboratory Pavlov loved to foretell the expected result of an experiment. With the passion and zeal characteristic of him he drew all his fellow-workers into this matter. A debate arose. Opinions differed. Passion flamed. Something resembling a sweepstake was arranged. But it might happen that the results turned out just opposite to those expected by Pavlov. Then Ivan Petrovich would exclaim: ". . . The devil! Nature is cleverer than we are . . . ." And he would immediately admit, "Of course, the final question belongs to reality. Who knows reality? We do not know all the depths of these processes and their origins." Not only in the laboratory but in every-day life also, Pavlov retained this ability to speak the truth. His was a noble, direct and honest character.

It is sad when the investigator is proud and has too high an opinion of himself. Pavlov taught youth: "Don't allow yourselves to be overcome by pride. On account of pride you will be stubborn where it is necessary to agree. On account of it you will reject useful advice and friendly assistance. Because of it you will lose your sense of objectivity." Modesty should be inherent in the true servant of science. The more experience and knowledge we accumulate the more clearly conscious do we become of how immeasurably great is the unknown in comparison with the scraps of knowledge torn off and perceived. As an example of exceptional modesty Pavlov quoted Newton, who, according to Leibnitz, when approaching the end of his days, said: "It has always seemed to me that I resemble a little boy playing with shells at the sea shore, while the entire ocean of knowledge spreads before me untouched." Modesty, the recognition of how little we know as yet, would by no means lead us to a sickly scepticism, to agnosticism. On the contrary, it should inspire us to the performance of new investigations, to rejoice in the victory of knowledge and to find pleasure in the consciousness of how much there is yet to know.

TORMENTING AND SAVING DOUBT

Incomplete knowledge gives birth to doubt. Pavlov lived through many periods of doubt during his sixty years of scientific activity. These doubts very rarely had a negative influence on the progress of his scientific work. He did not like to broadcast his doubts. Evidently from pedagogical considerations or in the aim of avoiding the spread of any kind of confusion among the ranks of his young collaborators, he very rarely expressed his doubts before them. But in personal conversations, even more often than in the laboratory, could be heard from his lips: "How pleasant that such a complex system as the higher nervous system of the animals lends itself to physiological analysis. But on the other hand, the thought arises: Everything is clear to us, but perhaps we are fooling ourselves." There were periods when tormenting doubts caused Pavlov much suffering, when the thought of the possible erroneousness of all his investigations arose. Ivan Petrovich survived these dreadful moments alone, passing through them as through a serious illness. He drank in strength and cheer from persistent intense thinking and found consolation in experimental work. In the laboratory he appeared gloomy and worried, but at the same time he listened to the reports of his collaborators on the current work with exceptional attentiveness and considered all details. Days passed and the crisis passed. The solution to the racking doubts was found in new experimental facts, in new achievements.

But there is also another type of doubt which Pavlov called the saving doubt. This kind of doubt is absolutely necessary for fertile scientific thinking. "You must constantly doubt and check up on yourself," he told his pupils. And the doubts must be all the stronger when the first obtained result of an experiment is the one desired. An experiment may be very easily incorrectly interpreted. The experimenter often sees that which he wishes to see, and not that which is present in reality. To avoid making mistakes it is necessary to outdo oneself in inventing numerous variations of the same experiment, to stand the experiment "on its head" in order to verify and control it. It was the strictness with which Pavlov approached the appraisal of factual material which secured the reputation of his laboratory. In cases of incongruity between the experiments performed by others and the data of Pavlov's, he never resorted to verbal criticism but immediately commenced verifying the experiments of others and only after that was done, did he come forward with a refutation of them. Pavlov had a natural aversion and hatred for all unverified and superficial conclusions.

SCIENTIFIC FANTASY

Without the participation of fantasy, scientific creation is impossible. Simple systematization or accumulation of facts is not sufficient to advance science. A leap in the development of science occurs only when scientific fantasy gives birth to new ideas.

Pavlov's thinking was based on concrete facts—he kept firm hold of the experimental basis. In this regard he was brilliantly able to discipline both his thinking processes and his speech. There was no cleavage between reality and his ideas. But in the process of work, when a scientific theory or a working hypothesis was formulated, Pavlov allowed himself, as he expressed it "to give free rein to fantasy." He seated himself comfortably in a convenient armchair, adopting a pose which was somewhat unusual to him, when the usual tensity of his muscles and his customary mobility vanished. His expressive and restless hands were folded together and stilled. His words flowed smoothly and calmly. Ivan Petrovich was thinking out loud. A strange feeling pervaded his listeners. It seemed as if the entire creative process was taking place before their eyes, as though under a bell-glass. In these minutes his mind rose to mighty generalizations. For many days after this the laboratory remained in a state of great excitement. The idea thus born was given over for "working out." There arose a harmonious structure of mental conclusions, logically deducted from the critical examination of facts. Those links which were lacking were supplied by new experiments. Aged links, which no longer held, were cast out without any regrets.

Collaborators also were allowed to give free flight to their fancy. Pavlov usually listened to these visionaries with a humorous smile of good will. Inventiveness was encouraged; but groundless, unsubstantiated fantasy was categorically judged. Wordy, artful designs artificially drawn in, in explanation of an experiment, evoked Pavlov's passionate disgust. He stopped listening, or if he found that sort of thing in books he threw the book aside with words of condemnation against the author: "This is false. Instead of concrete material, here is pure speculative philosophy. And I depend on practice. What are the words and thoughts of others to me!"

FOR THE NATURALIST THE METHOD IS EVERYTHING

New methods open new roads for the development of science. Pavlov profoundly understood and valued the significance of method in scientific research. ". . . Science moves by jerks, in dependence upon the successes made by the methods used," he said. "It is as though with every step of the method we rose one step higher and from this higher step were disclosed to us wider horizons containing objects previously invisible to us." The first task which Pavlov set himself when he began the study of digestion was the elaboration of methods adequate for the tasks of the investigation. Looking upon the organism as a complex system in a state of dynamic equilibrium, Pavlov clearly understood that the method of vivisection most profoundly disturbs the entire system as an entity. The results obtained from so-called acute experiments did not reflect the normal relations of the organism to its external surroundings. Under these conditions it was difficult to count upon discovering new laws. And so Pavlov introduced into physiology the method of chronic experiments. For this it was necessary to master and perfect surgical technique, and to introduce aseptic surgery into the field of physiological experiments. Pavlov did both. He became an expert surgeon, and devised new surgical operations. He performed exceedingly difficult and complicated operations on animals. For the first time a surgical section, satisfying all the requirements of the surgery of those times, was opened in a physiological laboratory on a par with the chemical, physical and histological divisions. The operation for the isolation of the stomach suggested by him is insurpassable in conception and delicacy of performance. How much labor and energy was spent on the elaboration of an extirpation method for the solution of the question of cortical localization! For every newly set task there must be found its own adequate method. What a limitless field of investigation of the higher nervous system was opened by the objective method of conditioned reflexes!

"MINE" AND "YOURS." WEDNESDAYS

Organization of the work is of great significance in scientific investigation. The selection of coworkers, the correct and able distribution of forces are important. It is well known that Pavlov's laboratories were a center of attraction to persons desiring to join in scientific work. Together with valuable and qualified workers, enthusiasts in their fields, there also came to the laboratory casual people, interested only in solving some private problem or simply desiring to "do" a dissertation. Thanks to Pavlov's gentleness and plain manner of dealing with every one who came to him to work, the doors of his laboratory were always wide open for both young and old scientists. Only in the last few years, because the laboratories were overcrowded, the influx of new collaborators markedly diminished. Pavlov himself selected new workers. He met all newcomers affably and attentively. Often, at the very first meeting Pavlov began telling of the current problems being treated in the laboratory, developed new theories, pointed out the difficulties of investigative work, etc. The conversation bore the nature of a simple, sometimes passionate, but always cordial chat. Pavlov completely forgot that his companion was still not well enough prepared to analyze all the complexities of the facts and suggestions laid before him. Pavlov shared his own thoughts with the newcomer. Under the influence of his warm reception and unusual simplicity, the embarrassment and the timidity of the first meeting disappeared. Pavlov's words already reached the mind of his listener whose thoughts, at first shyly and then more and more freely, began to follow those of Pavlov. At last came the moment when the surroundings were forgotten in the consciousness of the fact that one was listening to the great scientist. The enchanted listener sat motionless with wide-open eyes and eagerly caught at every word. Suddenly Pavlov would cease speaking. A quarter past five! Pavlov would jump up hastily, thrust out his hand in farewell and disappear from the laboratory. For a week such chats were repeated several times. Then the new coworker took his place in the laboratory and began preparatory work. During this period it was as though Pavlov had forgotten about him. His dealings with the new collaborator were restricted to brief comments or directions concerning concrete things directly concerned with the experiment in progress. Essentially Pavlov did not occupy himself with the individual education of each of his collaborators. This was done by the entire laboratory surroundings, the laboratory atmosphere, "in which," according to Pavlov's expression, "every one gives a little of himself but breathes in everything." The newcomer was tutored by the entire group of laboratory workers, by the personal example of Ivan Petrovich, through his boundless devotion to science, his ability to become engrossed in scientific work to the point of self-oblivion. And at the same time the tutoring was accomplished by Pavlov's ability to direct and command the laboratory in the sense of real leadership and making of plans. Ivan Petrovich always stressed that "we are all harnessed to one common work and each moves ahead according to the measure of his own strength and abilities."

The atmosphere of general interestedness, general participation in the work was created naturally and simply. Under the fresh impression of an experiment, excited by new thoughts, Ivan Petrovich went from one room of his laboratory to another and told his collaborators of the new facts just obtained. Since, with the course of time, not only the number of rooms but also the number of workers in the laboratory increased, it became impossible to include all the collaborators in his rounds. Then, upon Pavlov's arrival in the laboratory, all the collaborators would gather together and take part in the conversation.

Beginning with 1924 Pavlov organized "Wednesdays"—conferences including the workers of all the laboratories, which were held on Wednesdays under Pavlov's leadership. "Wednesdays" had a tremendous influence on the progress of investigations, on the education and unification of all the workers. "Wednesdays" were diligently prepared for not only by all the collaborators who were to report on the course of their work, but also by Pavlov himself. Before the conferences Pavlov carefully verified and thought over all factual material. After a short general introduction, in which Pavlov pointed out the relation of the particular investigations to the general problem with which the laboratory was occupied, the collaborators reporting summarized their experiments. Ivan Petrovich always demanded a brief, clear and concise report. He was interested in all details and himself checked and compared the records of the experiments. In connection with this his unusual memory was always astonishing. Sometimes the collaborator would forget the data from his own previous experiments. Then Pavlov would remind him. Pavlov possessed the remarkable faculty of retaining details from experiments in which several tens of collaborators and more than one hundred dogs were involved. After the report came the process of thinking out loud. Members of the audience contributed their comments, asked questions, requested explanations. Differences, heated arguments arose. There was never calmness or complacency during the discussion of scientific questions at these "Wednesdays." The atmosphere was always strained—in it was always felt the reflection of the fight for the power of man to change and influence nature. It was apparent that here a new world of conceptions was forged. At these "Wednesdays" as well as on all other occasions, Pavlov was capable of openly rejoicing about achievements and being infectiously merry. The conclusion of the conference was usually devoted to reading or discussing new articles or books which Pavlov received from all corners of the world and which his collaborators otherwise had difficulty in obtaining. Thus Pavlov led his pupils through a course in contemporary scientific literature in an interesting and imperceptible manner. Of exceptional interest were those "Wednesdays" on which Pavlov read his own articles, which were likewise subjected to discussion and criticism. With a noteworthy lack of pride and the author's self-love he made corrections on the spot if errors contradicting truth were found. Especially memorable is one of these "Wednesdays" at which Pavlov read his paper on "Conditioned Reflexes" written for the Medical Encyclopedia. This occurred on the eve of his eighty-fifth birthday. During the year Pavlov had been ill several times, and therefore some of his fellow-workers thought that age had put its stamp on his clear mind. There were even some "objective" proofs of this! For instance, Pavlov, for the first time in his life, got himself a note-book, but he used it very rarely, since he always forgot to make notes in it!

Pavlov said beforehand that he would read his recently concluded article "Conditioned Reflexes" the next "Wednesday." Always in such cases there was much excitement in the laboratory. All eagerly waited for Wednesday. At 10:15 Pavlov was already seated in his usual place at the table. Around him were about sixty students and co-workers. To begin with, Pavlov "lit into" the Encyclopedia which, in his opinion, only serves lazy people, and then becoming reconciled he stated—"But by the way, various sorts of people will read it, both clever ones and foolish ones, both those informed about questions regarding the nervous system and those not so informed. And I planned so that every one should gain some profit from reading this article. This explains the simplification, or rather, elementary exposition found in some parts of the article." After this short preface he began to read.

As everything that was written by Pavlov's pen, this article was the fruit of serious and prolonged work. But this was not a simple exposition of the teaching of conditioned reflexes. All the latest achievements of the laboratories and clinics were organically knit into the article. The question of confluence of physiological phenomena with the experiences of the subjective world is brilliantly revealed by Pavlov, the fundamental laws of the higher nervous activity are described so that every layman can understand them. All the exceedingly vast and complicated material is presented in a clear concise form. Evidently, while writing the article, Pavlov especially kept in mind the reader of an encyclopedia. The reading was concluded. An unusual silence prevailed in the auditorium. Strong emotional excitation was felt by all—the agitating emotion that comes from awareness of thoughts whose exceeding greatness and profundity are not quite realized yet—the triumph of a human mind which does not lend itself to the destroying influence of time.

The prolonged silence somewhat perplexed Pavlov at first, and then he angrily said: "I purposely read this article for you to criticize it, and you keep silent!" He brought his thought to a public court made up of his collaborators. But the "court" was held neither on that day nor later. It was too much for the audience to "pick up" all that which they had just heard. After that, for a long time it was said that Pavlov had given himself the best gift for his eighty-fifth birthday.

His fellow-workers were given much pleasure when Pavlov, in the second half of a "Wednesday," would suddenly become animated and with enthusiasm begin to relate his recollections of the days of his youth, of meetings with people, of past events in which he had participated. He talked in a masterfully expressive way and had a completely original style of speech.

The "Wednesday" program included a ritual for checking up on the time. In exactness and accuracy Pavlov was insurpassable. I believe he can only be compared with Kant, according to whose movements the inhabitants of Königsberg set their clocks. One minute to twelve o'clock the meeting was interrupted and Ivan Petrovich put his watch on the table, the collaborators doing likewise. The seconds were counted in expectation of the Leningrad mid-day signal—a cannon shot. Of course not all the watches kept perfect time—some watches were slightly ahead, others slow and that caused a perfectly natural variance in forecasts as to when the cannon would be let off. Even disputes would arise in the prevailing silence. Pavlov would stubbornly trust only his own watch and keep quiet. The shot! The triumphant voice of Pavlov rings out—"Splendid! It's absolutely exact!" When the cannon was abolished and the correct time announced by radio, a loudspeaker was placed in the auditorium and the ritual retained all its solemn significance.

In the constant mental intercourse it was really impossible to tell what belonged to one and what to another, what was "mine" and what was "yours." In his preface to "Conditioned Reflexes: an Investigation of the Physiological Activity of the Cerebral Cortex," Pavlov gave an excellent appraisal of this method of collective creative work.

"I have to express my warmest thanks to all my fellow-workers who joined their labor with mine in our common task. If I instigated, directed and correlated all our labor, I was myself continually influenced by the vigilance and resourcefulness of my co-workers."

THE TEACHER

Pavlov's importance and influence as a teacher was tremendous. He had a school unlimited by walls, and a countless number of students. Since 1876, from the time he was assistant to Ustimovich in the Veterinary Institute, Pavlov took the official title of teacher. Until 1924—when he left the Military Medical Academy—many members of the younger generations passed through his hands. His lectures left their indelible mark. The students clearly felt that his lectures were not only an exposition of physiological knowledge but that at these lectures, in experiments on the laws controlling the activity of the organism which were performed before their eyes, the entire process of scientific work from method to scientific thinking was disclosed and demonstrated. This always made an unforgettable impression, especially in combination with Pavlov's simplicity of exposition and clarity of thought, with his cordial, friendly attitude to youth. Many young doctors were schooled in his laboratory. A comrade at work, Pavlov knew how to combine a loving simple attitude with his high scientific authority. Recalling the years 1886–87, the period of his work under the direction of Pavlov, N. J. Chistovich wrote: " . . . I think that each of us feels a lively gratitude to our teacher not only for his talented leadership, but, chiefly, for the remarkable example which we saw in him, personally, the example of one wholly devoted to science and living only for science in spite of his exceedingly difficult material conditions—literally poverty."

Other evidence is given by a person who worked in Pavlov's laboratory only one winter (1907-1908). Minkovsky, seventeen years after he last saw Pavlov, characterized the image of his teacher thus: " . . . Intercourse with this fearless fighter, who boldly approaches even the most difficult problem and then never retreats from it until nature gives him an answer to the question he put to her, and who in the midst of his work constantly shares his pulsating scientific thoughts with his collaborators, has become for me the source of my love for experimental work. Faith in it as a most mighty means of natural scientific investigation has never left me since."

Many such testimonies can be cited. Only one thing is without question—that every one who entered Pavlov's laboratory left it sharing a great love for science, preserving in their hearts the image of an ideal truth-seeker.

Pavlov's audience was enormous. He read lectures to doctors, spoke for scientific societies and at congresses. He was listened to not only by the scientists of his own country but by those of the whole world. Among foreign colleagues he was given the title of citizen of the world. The last International Physiological Congress recognized him as the first physiologist of the world. The influence of Pavlov's ideas far transcends the boundaries of physiology and spreads to the various medical disciplines—psychology, biology and other branches of positive scientific knowledge.

Pavlov was known to millions of thinking people in the Soviet Union. His teachings on conditioned reflexes are particularly well known. His name is popular abroad among people standing far from physiology or even biology. As a great naturalist his name will be enrolled in the annals of science, where the name, Ivan Petrovich Pavlov, will stand together with the names of the great, whose works illuminate mankind's road to truth and perfect happiness.

Pavlov taught not only how to work scientifically, but how to live, how to love fatherland and man.

From an immeasurably rich nature, Pavlov, with the help of natural science, conquered all that life offers, all that is beneficial and pleasant. In this lies the true happiness of human existence. In the name of this happiness Pavlov gave his life to science.

WHERE OUR NOTABLES CAME FROM

By Dr. STEPHEN S. VISHER

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DESPITE much sarcasm expended on "The Brain Trust," every one knows that experts and other leaders play a large rôle in our country. They have done so since colonial days, and leadership is becoming increasingly important with increasing complexity of economic, political and social conditions.

Just as there are many sorts of leaders, so are there several different ways of considering their origins. First let us consider the rank of the various states and sections in the yield of notables. Next let us study the comparative yield of areas which differ with respect to such things as climate, ruggedness and wealth. Third, we shall compare the yield of farm, village and different types of cities. Then is considered evidence as to the types of homes which yielded many or few notables, largely a study of the occupations of the fathers of the notables, but some attention is given to religion and European ancestral origin. Finally, some tentative conclusions are offered.

To be recognized as a notable requires more than brightness, nobility of character or even of social desirability. Many bright people lack the ambition, health, education or opportunity to accomplish enough to win recognition as leaders.

Hence this study is of notables who have been so recognized by competent authorities. Several sizable groups are included: the members of the National Academy of Sciences; the scientists who were starred as especially distinguished, at different periods; the lesser scientists also sketched in Cattell's "American Men of Science"; members of the American Academy of Arts and Letters; painters, sculptors and architects of the National Institute of Arts and Letters; presidents of many leading colleges, superintendents of the school systems of numerous large cities, deans of famous schools of law and education; presidents of the American Society of Civil Engineers; labor leaders in "Who's Who in Labor," farm leaders in *Rus* and the millionaires studied by Sorokin. A special study was made of all persons sketched in "Who's Who in America," with the women considered separately. The details for each of these twenty-four groups can not be given here, of course, but some significant facts and conclusions are of interest.

PRODUCTION BY STATES AND CENSUS GROUPS OF STATES

The six groups of scientists and the eighteen groups of non-scientific notables studied reveal a peculiar concentration of birthplaces. In proportion to population, New England produced about twice as many as did the Middle Atlantic or North Central States, nearly three times as many as the Pacific States, about six times as many as the South Central States.

The southward decline in the yield of notables prevailed not only among the several census groups of states, but also, with very few exceptions, among the individual states. The chief exception is Massachusetts, which surpassed the more northern New England states. Elsewhere the southward decline prevailed almost invariably for the average rank, although in the yield of some particular sort of notable there are exceptions. For example, among the Pacific States, Washington led for most types; next came Oregon, and last came California, which, however, led in members of the

National Academy of Sciences and artists.

Another generalization as to the regional origin of notables justified by the abundant data here summarized is that states that produce few scientists also produce few artists or administrators, and *vice versa*.

The changes from decade to decade in the yield of ten sorts of comparable notables permit a third significant conclusion as to regional productivity, that there has been a progressive decline, at least since about 1860, in the preeminence of New England in the production of notables in proportion to population and a lesser decline for New York and other seaboard states. In contrast, there has been a relative increase in the North Central States and, to a lesser degree, in the Western States. Systematic changes in productivity indicate that changes within the area are important in determining its rank.

Production by Type of Area

The conspicuous regional differences in the yield of notables may advantageously be considered with our attention focused on contrasts in the environment. First let us consider climate. Ellsworth Huntington's theory that a fairly favorable climate is a prerequisite to a high civilization, and hence to the yield of numerous leaders, is not adequately tested by the data here studied, as all parts of the United States which were well-populated when these notables were born have at least a fairly favorable climate. The southward decline is, however, completely in accord with that theory. It may be partly caused by the selective effects of the winters. The long, cold winters of the more northern states are unfavorable to Negroes and are not at all to the liking of the easy-going type of whites, both of whom are rous in the South. Consequently, although Missouri and Virginia, for example, contain many superior white people and have yielded many leaders, their contribution to leadership, in proportion to population, is notably reduced by their large population of "easily satisfied" people. Abundant evidence, however, indicates that while climate may help explain the general distribution, it is not paramount. For example, nearby areas with essentially the same climates differ greatly in the yield of notables, *i.e.*, the southeastern and southwestern quarters of both Indiana and Illinois, southern Michigan and northern Indiana, and Rhode Island and Connecticut.

Another often held theory is that "as wealth increases so does yield of leaders." True, many relatively rich areas produced more leaders than did certain poorer ones. Thus in each of the six central states studied in detail, the areas relatively productive of notables have distinct geographic advantages over various other areas which are less productive. But, on the other hand, various rich areas have not been nearly so productive of leaders as some poorer areas.

Satisfactory estimates of the comparative wealth of different areas are not available, partly because there are so many aspects of wealth. Nevertheless, the Census Bureau's estimate of the wealth of the states nearest the birth of the notables studied throws light on this theory. The resulting map of the average wealth per square mile resembles in a general way the map of the yield of notables. But the exceptions clearly suffice to prove that wealth per square mile is not a predominant factor. For instance, the Rocky Mountain States have only about one third as much as the South Central States, but have yielded more than twice as many notables proportionately. When individual states are considered, more striking discrepancies are disclosed. Thus, Louisiana had nearly twice the wealth but only one thirtieth the productivity of Maine, and Rhode Island over twice the wealth of Connecticut but less than half the productivity. If instead of the wealth per area, the wealth per capita is considered, even less correlation occurs.

Of the various sorts of wealth, the one most widely thought of as "real wealth," namely mineral wealth, seems indeed to be distinctly unfavorable to the yield of leaders. At any rate, almost none were born in the mining communities of America, except a few in parsonages.

The statement of Frederick J. Turner, the eminent historian, that "It often seems to be largely a matter of topography; the level lands yield leaders as well as crops, while the rugged lands produce few of either," led to a special study of the correlation between topography and yield of leaders. In Ohio the area which yielded fewest notables is, indeed, almost the most rugged, but another area which yielded few is flat and agriculturally highly productive. Moreover, the very hilly section of northern Ohio yielded many. In Indiana, likewise, the most rugged area yielded few notables, but much smooth land did no better, and one of the counties which yielded most is one of the roughest. In Illinois, similarly, a large share of the relatively sterile southern section, containing half of the state's population of 1870, is smoother than much of northern Illinois, the birthplace of many notables. In Wisconsin, the relatively hilly unglaciated section yielded few notables, but smooth areas elsewhere were equally sterile, while other hilly areas were productive. In Kentucky, finally, the most level, fertile part of the state, at the west, yielded almost no notables. Thus it seems evident that topography is not a major influence.

As a final section of this part, let us consider stage of settlement and density of population. It has often been asserted that frontiers can not be expected to produce leaders, as the people are engaged in "hewing homes out of the wilderness." Evidence supporting this theory is the fact that there was, in the Midwest, an increased yield of starred scientists in proportion to population from 1860 to 1870 or 1880, and also that the southern halves of the populations of Michigan and Wisconsin yielded many more notables than the northern, which had not then developed beyond the cruder stages of frontier conditions. Contrary evidence is the declining yield in proportion to population that occurred in the Eastern States, and more recently in various parts of some of the North Central States. These declines almost disprove this theory.

Moreover, although southern New England was the first section to be well-peopled and to pass beyond the agricultural stage, it was in these regards only a little ahead of Pennsylvania, which yielded only one third as many notables, relatively. Likewise, Quebec, the first Canadian province to become populous, ranks lowest in the relative yield of Canadian notables. Similarly, densely settled Rhode Island was far excelled by rural Vermont in the yield of notables.

YIELD OF CITY, TOWN AND COUNTRY

It has often been asserted that most famous Americans were born on farms. On the other hand, certain studies of small groups of eminent people have revealed that many were born in cities. In order to throw light on this question a "special request" was sent to all persons sketched in one edition of "Who's Who in America" to indicate the type of place in which they were born. Replies from 18,400 persons indicate that approximately equal numbers were born on farms, in villages and towns, in small cities and in large cities or their suburbs.

At the 1870 census, the census nearest to the birth of most of the notables, about one tenth of the people of the United States lived in cities of over 50,000; one ninth in cities of 8,000 to 50,000; one twelfth in small places; and almost seven tenths on farms.

Thus in proportion to population, cities contributed nearly six times as many notables as did farms; villages nine times as many; and suburbs eleven times as many. This does not prove that early life on a farm was unfavorable to future eminence. Indeed, many famous men who were not born on farms spent part of their early life there and considered the experience helpful. In fact, many such famous men have, on occasion, spoken of having been "reared" on a farm.

Further information was obtained by as detailed a study as possible of the birthplaces of the more eminent scientists, artists, authors and engineers, and also of all types of prominent people born in Indiana and five nearby states.

Of the most eminent group of notables, the largest cities yielded many more than their proportionate numbers, the cities of the northeast and their suburbs yielding more than one fourth of the total and the large cities of the South almost a half of the few who were born in the South. Boston and its suburbs were remarkably productive, while New York and Philadelphia and their suburbs also ranked very high. In the Midwest, however, many of the more eminent notables, as well as the lesser notables, were born in villages and a considerable number on farms. Very few of the prominent women, however, were born on farms.

Of the cities and towns of the Midwest, especial note was made as to the relative contribution of county seats and college towns. The average county seat yielded notables at about three times the rate of the rest of the state, and the smaller county seats yielded more relatively than did the larger ones. Likewise, the fourscore cities and towns of the Midwest which contained colleges yielded an average of four starred scientists each, and many other notables, an average productivity of fully twice that of other cities in these states. Approximately one third of the many starred scientists born in Ohio and Illinois were born in college towns and more than half of those of Kentucky. Although college towns yielded relatively many notables, surprisingly few graduated from the college in their birthplace; indeed many graduated from out-of-state colleges. For example, only six out of forty-seven Hoosier women sketched in "Who's Who" graduated from an Indiana college. Only two fifths of Wisconsin's starred scientists did their college work in Wisconsin, and more than half of Michigan's left Michigan for their college degrees. This suggests that the young people, later to become distinguished, were quick to see imperfections in their local institutions and, desiring a superior training, went elsewhere.

In the Midwest, the largest cities of each state did less well than the smaller, and those which grew most rapidly yielded proportionately fewer than other cities in the same state.

Thus it appears that the parents of notables (as might be expected of alert people anxious to better their conditions and possessed of the requisite boldness, energy and resources to do so) gather in the centers of population, as here there are more opportunities to use their skill. In the Midwest, although in 1870 nearly four fifths of the population was rural, the towns already contained, it appears, a considerable share of the parents of leaders. As opportunities for gaining a livelihood in the towns and cities increased, progressively larger proportions of the most alert, ambitious people moved to the more attractive cities, often the county seats with colleges. But the cities also attracted many manual laborers, so that, in proportion to population, the highly intellectual type commonly forms a smaller percentage, except in choice residential sections and suburbs, than in the smaller county seats. Nevertheless, in the yield of the most outstanding artists, architects, authors and scientists, the large cities led in proportion to population.

HOME ENVIRONMENTS OF NOTABLES

The questionnaire sent to all subjects of sketches in "Who's Who in America" for 1922–1923 included a request for information as to the occupations of their fathers. The 18,400 replies revealed that business men and professional men each fathered slightly more than a third of the American notables born about 1870 (35 and 34 per cent.), and farmers almost one fourth (23.4 per cent.). Skilled laborers, however, fathered only a small share (6 per cent.), and the vast number of unskilled laborers almost none.

In proportion to their numbers in the general population at the 1870 census, professional men fathered more than twice as many notables as business men, nearly twenty times as many as farmers, about forty-five times as many as skilled laborers, and 1,340 as many as unskilled laborers. Farmers, on the other hand, fathered one fourth less than their proportionate share, but did much better than other manual workers, contributing more than twice as many as did skilled and semi-skilled laborers and seventy times as many as the nearly one half of the men of the nation who were classed as unskilled laborers. (Farm laborers were included here.)

Thus, although about 1870, only one unskilled laborer in about 38,000 fathered a son or daughter sufficiently noteworthy to win a place in "Who's Who," one skilled laborer in 1,300 had that distinction, one farmer in 550, one business man in 62, and one professional man in 27. In other words, the yield of these notables by the higher types of artisans was about thirty times as great as by the unskilled laborers, whereas the farmers did seventy times as well as the unskilled laborers, business men six hundred times as well, and professional men nearly 1,400 times as well.

As previous studies by Cattell, E. L. Clarke, C. M. Cox, Havelock Ellis and others had indicated that many notables were sons of professional men, the questionnaire sent to the persons sketched in "Who's Who in America" requested a classification of such fathers. Those whose fathers were clergymen were asked to state the denomination, and for other professional men, the profession. Exactly one ninth of the notables reported their fathers as clergymen, which, when due account is taken of the number of Protestant clergymen in America at that time, means that more than twice as large a percentage of clergymen's sons became such conspicuously valuable members of society as to be sketched in "Who's Who" as was the case with the sons of other professional men combined. Thus Protestant clergymen contributed, in proportion to their numbers, four times as many eminent sons as did business men, thirty-five times as many as did farmers, and 2,400 times as many as did unskilled laborers.

The comparative yields of notables by the leading professions and religious denominations are also of interest. From the available data, it appears that, about 1870, one engineer in 196 fathered a notable, one physician in 129, one Methodist clergyman in 97, one lawyer in 66, one sea-captain or pilot in 47, one Baptist clergyman in 44, one Presbyterian clergyman in 11, one Episcopalian clergyman in 9, one Congregational clergyman in 8, and one Unitarian clergyman in 7.

Thus about six times as large a percentage of the children of Episcopalian, Congregational and Unitarian clergymen later were sketched in "Who's Who" than was true for Baptist clergymen, and twelve times as for Methodist clergymen. The lower rank of these latter denominations is partly explained, however, by the large number of Negro pastors in the Southern (African) divisions of these denominations, and also by the fact that some other divisions of Methodists and Baptists then had relatively low educational requirements for their clergymen.

The relatively low rank of engineers in fathering notables will surprise many

who know how capable the best engineers are, but many persons counted by the census of 1870 as engineers were not highly trained men. Likewise many physicians at that time had no high-school training and only a few weeks in medical school. The better physicians were another sort. (Cattell found that of nearly 900 starred scientists, physicians fathered three fourths as many as did clergymen.)

CONCLUSION

In conclusion, it is therefore apparent that a small portion of the men of 1870 fathered a large share of the present leaders Most of these fortunate men belonged to the so-called upper classes. However, the several geographic sections of America varied in their yield of notables only roughly in accord with their relative numbers of such classes.

The proper interpretation of this concentration is in dispute Advocates of the theory that environmental influences dominate assert that the classes that produce most leaders do so because they have the best opportunities for cultural and physical development They claim that there are many children of unskilled laborers who are as capable as the children of the upper classes, and also point out that the South was economically badly handicapped by the Civil War On the other hand, advocates of the theory that hereditary influences predominate declare that children of unskilled laborers, when adopted into homes of professional men or otherwise given comparable opportunities, nearly always fail to become leaders. They likewise declare that the superior economic status of the fathers of most leaders is the result of their superior qualities of mental alertness, earnestness, ambition and vitality.

Advocates of the theory that social selection is very important find much support in such data as are here summarized. They point out that the mentally alert people are chiefly found in occupations where their mentality is most advantageous, while the mentally dull are chiefly found in occupations calling for physical strength or routine work. Selection of another type is illustrated by immigrants of exceptional ability. These have come from numerous areas; for example, a very considerable number of eminent Americans are of German descent, especially of the liberals who came over following the revolution of 1848. Scotland, both directly and via north Ireland (the Scotch Irish), also has supplied many ancestors of eminent Americans. But according to much evidence, by far the largest group of American leaders are descendants of emigrants from East Anglia, England, the district which, according to Havelock Ellis ("British Genius"), yielded relatively many eminent British and most of the Puritans of New England, the Quakers and the Cavaliers of Virginia. (Cattell found that most of the scientific leaders of 1903 were at least half Puritan in descent). The westward spread of the descendants of the Puritans out from New England clearly helps explain the geographical contrasts in the yield of notables Conversely, their partial submergence numerically by less valuable stocks largely produce the decline in the yield of notables in proportion to population in New England and various more western areas.

Finally, areas yield most notables which contain most mentally alert, ambitious, persistent, energetic people possessed of high ideals. Such people seek opportunities to use their abilities; they appreciate congenial associates and therefore congregate in desirable towns and in choice residential districts or suburbs of cities. Since Quakers, Scotch, Germans of 1848 and especially Yankees include many people of this type, many notables were born wherever such stocks formed a relatively large share of the population.

CHIPPEWA INTERPRETATIONS OF NATURAL PHENOMENA

By Sister M. INEZ HILGER, O.S.B.

ST. MARY'S ACADEMY, ALTOONA, WISCONSIN

THE following notes on the interpretations of natural phenomena by the Chippewa were gathered on the Red Lake Reservation of Minnesota in the summers of 1932 and 1933 and on the Lac Courte Orielle, the Lac du Flambeau and the La Pointe Reservations of Wisconsin and the L'Anse Reservation of Michigan in the summer of 1935.

''No one kept account of years in early days.'' Months were recorded by moons and were known by natural events which occurred from new moon to new moon. Days were counted by nights.

The sun, when eclipsed, was either dying or dead, or being hid by some one. Men shot arrows toward the sun until it reappeared, believing that thereby bad luck was killed No explanation was known for eclipses of the moon.

The sun and moon represented persons. The moon at one time was a man who had gone to fetch some water and was taken up into the air. Hence, in the full moon one sees a man with a bucket. Stars were not personified.

Thunder and lightning are caused by Nĕḿĭkĭg, the thunder bird. Nĕḿĭkĭg flashes lightning when he looks about him to see in what direction he wishes to fly. Immediately after he has taken a glance, he flaps wings and tail, proceeds on his journey and so causes the thunder. When a thunder-storm rumbles through the skies, an old Chippewa may offer tobacco on the fire, smoke his pipe, step out-of-doors, raise his hands toward heaven, and say to the thunder: ''Don't scare the children! Keep quiet! Go back!'' The storm invariably passes over. ''Not every one can do this effectively; only those who have dreamed of thunder.''

The power of the thunder bird is shown in the following story:

> A long time ago before the whites came, an old Indian was hunting beaver. The Indians at this time tempered copper into spearheads. Beaver were speared by means of these copper spearheads. This man had a blanket over his head to see where the beavers were. A bird picked up the old man with the blanket and took him up among the clouds. He was afraid to open his blanket to peek out; when he did, he saw the blue sky. The thunder bird had picked him up. He was gone for four years. When he returned to earth the lightning was so strong near him that he couldn't stay near his own people.

An old theory is that the thunder bird also causes northern lights. Other explanations are that they are light reflected from water or ice or that they are caused by an electric storm raging in the far north, or that winds are ''blowing furiously high up in the air.'' Strong winds or severe storms invariably follow two or three days after the appearance of northern lights.

The rainbow, nȧgwȧ'ȧb, is the color of the sleeves of Magĕgĕḱwā̆, a woman who raises her arms over the sky so that her fingers interlock. The appearance of the rainbow is a sign that the rain has ended and that good weather will follow.

One informant said that one night, when he was a little boy, the sky became red and then white (from a comet). ''The stones were red from the reflection. It was night but it seemed like daylight. This thing had a long tail which was lighted!'' His mother predicted some catastrophe, and soon there was war between the North and the South. His father went away and did not return for three years.

The sun marked the directions by day; the north star, by night. Chippewa Indians following a trail marked a turn toward the setting sun by fastening to a tree a piece of birch bark containing a + sign. A — sign indicated a turn toward the rising sun. Sundials were at times used in finding directions. More often, however, they indicated the time of the day.

Sundials, to-day, are used primarily when camping away from home and are still made in the same manner as in the early days. On a clear night a man will stake a stick, about a yard high, and lying flat on the ground move about until the stick and the north star are in line. A second stick of about the same length will then be laid to the south of the first and in line with it and the north star, and be staked about a yard from the first. (An informant on the Lac Courte Orielle Reservation did not stake a second stick but simply drew a straight line north and south through the first stick). In the morning a line is drawn through the base of the south stick at right angles to the line of the two sticks. When the shadow of the south stick falls on the westerly line it is about six o'clock in the morning; when it falls in line with the north stick, it is noonday; when on the easterly line it is nearly six o'clock in the evening. The remaining hours of the day are only approximately read.

The method used by an old Indian at Red Lake varies somewhat from the above. Two sticks are staked as described above. In the morning, a third one is staked to the south and in line with the first two. A semi-circle is then drawn through the third stick, convex to the southward. When the shadow of the third stick falls west and tangent to the circle, it is approximately six in the morning; when it falls in line with the two sticks to the north, it is noonday; when, to the east and tangent to the circle, it is approximately six in the evening.

The old Chippewa, too, have ways of foretelling weather. Rain may be expected when birds abruptly end their songs and leave them unfinished. When small lizards that live in decayed wood whistle notes not unlike those of an ordinary human whistle, heavy rainfall and storm are on their way. The singing of tree toads also predicts rainfall. A rainbow in the west predicts more rain; in the east, clear weather. A small circle about the moon never fails to forecast bad weather; a large circle indicates warm weather. Northern lights, as noted before, forecast a storm. Some women can predict weather at maple-sugar making time by the way stars and clouds hang in the heavens. Sundogs in the fall predict heavy snowfalls for the winter.

Throwing a rabbit skin into fire will cause a snowstorm or bring a north wind. Any one wishing the wind to blow in a certain direction must shoot arrows in that direction. Swinging one's hand back and forth in the water while rowing to places may produce a storm.

Drowning dogs or cats in Keweenaw Bay invariably brings a storm. The water will not tolerate decayed matter, and hence produces a prevailing wind in any direction until the dead animal has been landed on shore. One day, two men, hoping to have a favorable wind for a fishing expedition, threw a cat into the bay. They were not disappointed; the wind blew favorably for three days. In early June of 1935, an informant accompanied by two men went out to fish. He noticed a bag near one man and said, "What have you there?"

"A cat that I'm going to drown," the other answered.

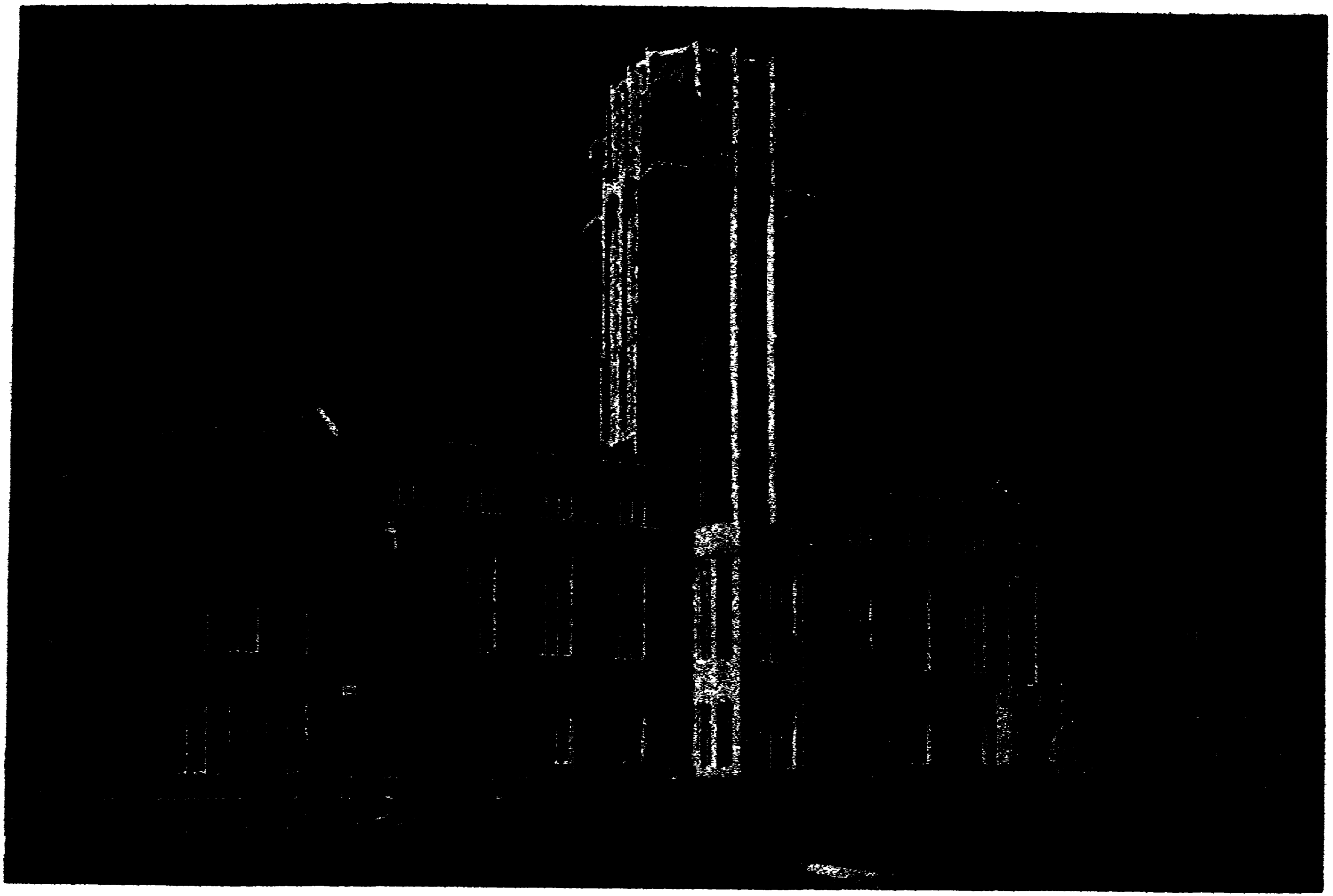
"Don't put that cat into the bay or you'll have a wind!"

While they were rowing, a storm suddenly came up.

Our informant inquired, "What did you do with that cat?"

"I threw it into the bay."

"Well, there is your storm!"



THE MARY REED LIBRARY OF THE UNIVERSITY OF DENVER

WHERE THE HUNDREDTH MEETING OF THE AMERICAN ASSOCIATION WAS FORMALLY OPENED WITH A RECEPTION.

THE PROGRESS OF SCIENCE

THE HUNDREDTH MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THIRTY-SIX years ago the association held its fiftieth meeting in Denver. The one hundredth meeting, held during the week of June 21, once again brought home to the citizens of Denver the fact that men and women who devote their lives to the pursuit of scientific inquiry are not necessarily dry, self-absorbed and technical. On the contrary, contact with the members of the association showed them to be surprisingly genial, kindly and sympathetic; and in many of them was found a fine flow of humor flavored with a wit which was none the less attractive because it carried with it no sting.

The Denver meeting was particularly notable for two features: first, the Southwestern and Pacific Divisions held joint meetings with the association; and, second, there were an unusual number of social functions and outings for the members and their guests. Dinners, teas, luncheons and excursions gave the visitors ample and pleasant opportunity to meet and mingle with local members, to see and appreciate Denver "from the inside" and to enjoy the mountain scenery of the district.

The meeting was formally opened with a reception on the evening of Monday, June 21, in the spacious Renaissance Room of the Reed Library of the University of Denver. This affair was well attended and was, to a large extent, responsible for the feeling of general good-fellowship which pervaded the group thereafter.

In all, some 590 papers were presented during the sessions of the various sections. It would be fruitless, if not impossible, to give here any adequate discussion or description of these sessions; and, in any event, detailed reports have been made through other media.

As usual, however, the more general or popular sessions attracted the most attention. These comprised three evening lectures by prominent scientists and two "special events" presented at afternoon meetings. The Maiben Lecture, on Wednesday evening, was given by Professor Nevil V. Sidgwick, of Lincoln College, University of Oxford, on the subject "Molecules." Professor Sidgwick first reviewed briefly and concisely some of the more pertinent facts and fancies of the kinetic theory of chemical action and their bearing on the formation and decomposition of molecules. The rest of his time was spent in a discussion of the factors which control and limit the phenomenon of "life"; and, in the end, to the conclusion that this phenomenon must be confined to very few localities in the entire universe. In fact, Dr. Sidgwick stated, it is a safe bet that our earth and probably only two of the other solar planets could possibly sustain life, regardless of the form or type taken by the living organism.

On Thursday evening, the John Wesley Powell Lecture was given by Dr. A. E. Douglass, of the University of Arizona, on the subject of "Tree-rings and Chronology." Dr. Douglass set forth his findings on periods of drought and rainfall as shown by the size and types of tree-rings. After tracing out the method of determination of chronology and local history from the appearance of logs and timbers used in old buildings of the Southwest, Dr. Douglass attempted to tie up his deductions with sun-spot cycles as a means of accounting for the apparent periodicity of the drought cycles.

A feature not listed on the program followed this lecture—a showing of some truly beautiful colored (kodachrome) moving pictures of the growth of crystals under the microscope. Since these pictures were taken in polarized light, the crystal growth was attended by astounding and yet pleasing color changes.

Dr. A. J. Carlson and Dr. Walter Bartky, of the University of Chicago, put on a demonstration of the methods being utilized by that institution for making

MEMBERS OF THE EXECUTIVE COMMITTEE OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

FRONT ROW, LEFT TO RIGHT: E. G. CONKLIN, J. MCKEEN CATTELL, F. R. MOULTON; BACK ROW, LEFT TO RIGHT: R. T. CHAMBERLIN, G. N. LEWIS, OTIS T. CALDWELL.

science not only popular but convincing to the younger generation. Dr. Carlson showed two films (movies), the first entitled "Body Defenses against Diseases," and the second "The Heart and Circulation of the Blood." These films were prepared and are being used for freshman instruction. They combined most ingeniously photomicrography, animated drawings and sound effects to give a vivid and forceful presentation of their subjects. Dr. Bartky's film was entitled "Exploring the Universe." It depended almost entirely on mechanical devices to show the apparent and real motions of the stars and to compress into a few mundane moments the celestial events of many millions of years.

On Thursday afternoon, Chancellor David Shaw Duncan, of the University of Denver, presided over a symposium on the "Scientific Aspects of the Control of Drifting Soils," a subject of immediate and most practical importance to the nation in general and to the inhabitants of this region in particular.

To one who had the good fortune to meet and talk with many of the prominent members during the week of the meeting and who attended several of the technical and popular sessions, it was evident that the aims and purposes of the association were adequately and pleasantly fulfilled at this meeting. As a means of bringing together the best scientific minds of the country, for formal and informal discussion of those particular and general subjects which concern us all; to break down the barriers of specialization and to promote the integration of our hard-won knowledge of this quaint world in which we find ourselves; to help, in however faltering and fitful a way, to a solution of the problems which puzzle us and to aid in the alleviation of the ills and pains that beset us—these objectives were brilliantly attained.

T. P. CAMPBELL

THE AWARD OF THE FRANKLIN INSTITUTE MEDALS TO DRS. MILLIKAN AND DEBYE

In recognition of their efforts "to advance the knowledge of physical science and its applications" the Franklin Medal and Certificate of Honorary Membership was awarded this year to Dr. Robert Andrews Millikan, director of the Norman Bridge Laboratory of Physics, California Institute of Technology, Pasadena, and to Dr Peter Joseph Wilhelm Debye, director of the Kaiser Wilhelm Institute of Physics, Berlin, Germany, by the Franklin Institute of the State of Pennsylvania.

The Franklin Medal is awarded annually from the Franklin Medal Fund, founded in 1914 by Samuel Insull, Esq., "to those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Institute, acting through its Committee on Science and the Arts, have done most to advance a knowledge of physical science or its applications."

Dr. Millikan received the medal "In recognition of his isolation and measurement of the fundamental unit of electricity, the electron; the photo-electric determination of the fundamental constant of radiation, Planck's constant; the extension of the ultra-violet spectrum by two octaves to join the spectrum of soft x-rays; and the study of the nature and the properties of a very penetrating radiation of cosmic origin."

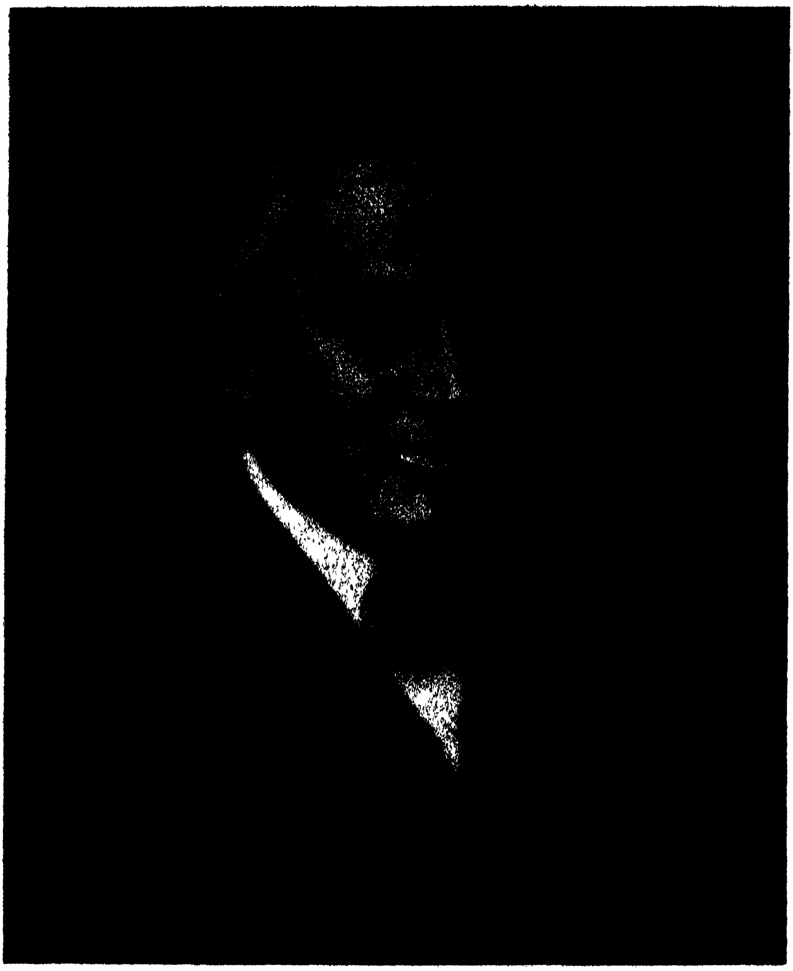
Because of his six weeks' lecture tour in Europe, including the delivery of the Joly lectures in Dublin, from May 1 to 12, inclusive, and his lectures in Scandinavian countries under the auspices of the American-Scandinavian Foundation, Dr. Millikan was not able to receive the award until after his return from Europe on June 25.

Dr. Debye received the medal "In recognition of his fundamental conception and masterly development of the theory that the molecules of many substances possess permanent dipole moments—a theory of great value in stimulating a vast amount of fruitful research on the electrical properties of insulators; his extension and generalization of Einstein's theory of the specific heats of solids; and his work, in collaboration with Huckel, on a theory of the thermodynamic properties of electrolytic solutions—work upon which the whole modern theory of electrolytes is based."

Since Dr. Debye is a Dutch citizen, the medal and certificate were received for him by Count van Rechteren Limpurg, chargé d'affaires of the Netherlands, Washington, D. C.

Dr. Charles P. Smyth, of Princeton University, read Dr. Debye's paper on "Structure in Electrolytic Solutions," which is a brief presentation of the foundations of the classical theory of solutions as laid by Van't Hoff, Arrhenius and Ostwald. For many years no success was reached in dealing with strong electrolytes. This led up to the more modern theories of solutions. Ghosh started from the idea that in a solution of sodium chloride the ions acted so strongly on each other that even in solution an arrangement of sodium and chlorine ions was established as in the solid crystals. Debye, however, considered it impossible that the tendency to produce such an arrangement could be strong enough to bring the lattice-order into real existence. To describe the significant properties of the arrangements of ions in a solution Debye introduced the idea of the ionic cloud.

Debye states: "If one considers an electrolytic solution, for example, a solution of sodium chloride, from the outside, so to speak, then in a specially fixed element of volume in a time-average, just as many positive sodium as negative chlorine ions will be found. Quite different is the picture when the observer is thought of as fixed to one of the sodium ions so that he follows all its movements



DR. ROBERT A. MILLIKAN

and observes his surroundings from this moving point. Then he will find that chlorine ions are favored, especially at shorter distances, and their number in the time-average exceeds that of sodium ions. We can thus speak of a cloud of electric charge, from which every point has in time average a particular charge density of opposite sign throughout to that of the central ion, but less dense the further the point under consideration is from the center. This is the structure which must take the place of the crystalline structure pictured by Ghosh."

Among other presentations were five awards of the Elliott Cresson Medal. This was founded in 1848 by Mr. Cresson, of Philadelphia, Pa., a philanthropist and successful merchant, who lived from 1796 to 1854. The medal is awarded "for discovery or original research, adding to the sum of human knowledge, irrespective of commercial value; leading and practical utilizations of discovery; and invention, methods of products embodying substantial elements of leadership in their respective classes, or usual skill or perfection in workmanship." The recipients were:

Dr. Carl D. Anderson, California Institute of Technology, Pasadena, "In consideration of his discovery of the positron."

DR. PETER JOSEPH WILHELM DEBYE

Dr. William Bowie, U. S. Coast and Geodetic Survey (retired), Washington, D. C., "In consideration of his contributions to the science of geodesy, particularly with reference to the theory of isostasy, the applications of which he has extended to problems in general geophysics and geology."

Mr. Jacques Edwin Brandenberger, Neuilly-sur-Seine, France, "In consideration of his invention and development of the process of manufacture of continuous transparent sheets of regenerated cellulose which have found a widespread use in industry."

Dr. William Francis Giauque, University of California, Berkeley, "In consideration of his outstanding contributions made to our scientific knowledge in the attainment of temperatures approaching within one fourth of one degree of the absolute zero and of his systematic observance and investigation of various substances at these low temperatures," and

Dr. Ernest O. Lawrence, director of the Radiation Laboratory, University of California, Berkeley, "In consideration of his development of the cyclotron, an apparatus for accelerating ions, which embodies a high degree of technical skill and is of material use in extending the knowledge of nuclear physics."

On the evening of the same day a subscription dinner was given in Franklin Hall of the institute, with Philip C. Staples, president of the institute, presiding. The medalists were introduced, and Count van Rechteren Limpurg, representing Dr. Debye, spoke in appreciation of the honor conferred upon his countryman.

Guy Marriner, associate director in charge of music at the institute, discussed Benjamin Franklin, the musician, and illustrated his talk on the pianoforte and glassychord. There was also a demonstration of a new musical instrument, the oscillion, designed and played by Dr. W. E. Danforth, Bartol Research Foundation of The Franklin Institute.

A. B. H.

THE HAYDEN PLANETARIUM-GRACE PERUVIAN ECLIPSE EXPEDITION

THE recent total eclipse of the sun began at sunrise on June 9 on the Pacific Ocean near Australia and, crossing the date line once and the equator twice in its course, ended on the coast of South America at sunset on June 8. It was observed in its early path from a "desert island" by the expedition of the National Geographic Society and the United States Navy; its final darkness fell on the cameras of the Hayden Planetarium-Grace Expedition in Peru, directed by Dr. Clyde Fisher, head of the Planetarium

Hayden Planetarium-Grace Eclipse Expedition.

IN THE ECLIPSE CAMP NEAR TRUJILLO.

LEFT TO RIGHT: DR. YAMAMOTO, FAMOUS JAPANESE ASTRONOMER, DR. GODOFREDO GARCIA, CHIEF OF PERUVIAN ASTRONOMICAL COMMISSION, MRS. ISABEL LEWIS, OF THE U. S. NAVAL OBSERVATORY, AND DR. CLYDE FISHER.

The South American expedition operated in five sections, partly for variety of observation and partly for certainty of observation in the event of local clouds. The eclipse was fortunately visible to every division and records were brought back from stations ranging from sea level to the sub-stratosphere.

The photographic equipment of past expeditions was augmented by motion picture cameras with color films. One of these was carried to 25,000 feet of altitude in the Panagra plane "Santa Silvia," where three operators, including Major Albert W. Stevens, made pictures as they breathed through oxygen tubes. With their cameras blanketed against the cold, they obtained large images of the corona with exposures of a twentieth of a second, as well as pictures of the receding shadows on the clouds and Andes Mountains.

Over two miles above sea level, the members of the Cerro de Pasco division made photographs of the corona, sketches of the prominences and the frantic beginnings of four paintings depicting phases of the eclipse.

In the yard of an ancient adobe church at 12,000 feet was a station where the Columbia Broadcasting System amid much clamor from the natives described the event to listeners in the United States.

After eight successive days of cloudiness during rehearsals at a 10,000 foot station, another division carrying huge cameras moved just before the eclipse to a pre-Inca fort, named Huecor, at 2,400 feet.

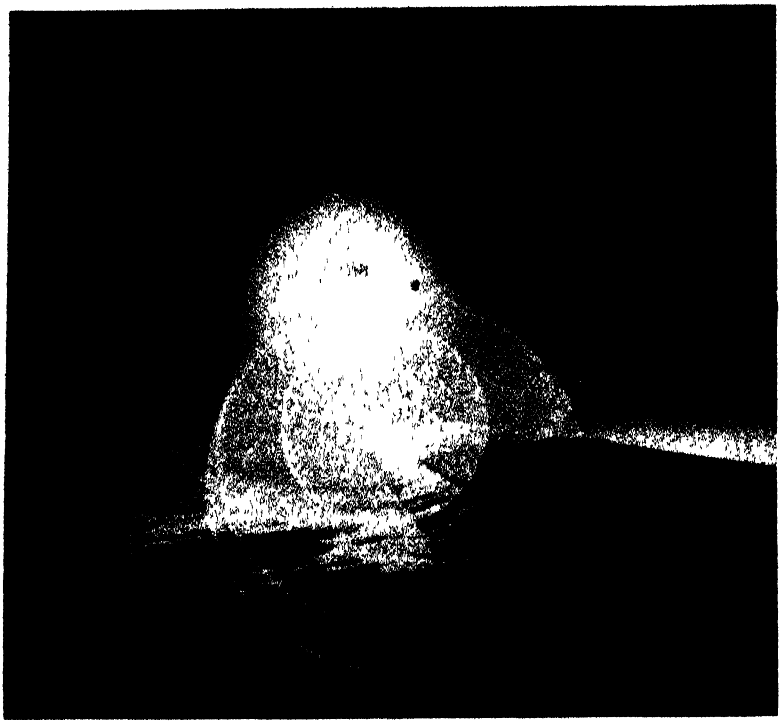
At sea level, Dr Clyde Fisher's Huanchaco division, due to its extreme western position, enjoyed the highest sun, 9½° above the horizon at mid-totality.

The "first contact" of the moon with the sun occurred at 4:15 P.M. At 5:18 came the "second contact" or the beginning of totality, which lasted two minutes and thirty-three seconds, the longest eclipse in over a millennium Just at "second contact" appeared a "diamond-ring" effect and the corona. The famous "diamond-ring" is formed by the thin

Hayden Planetarium-Grace Eclipse Expedition.

ECLIPSE OBSERVERS AT CERRO DE PASCO.

FROM LEFT TO RIGHT: D. OWEN STEPHENS, ASTRONOMICAL PAINTER, WILLIAM H. BARTON, JR., MRS. BARTON, MISS DOROTHY A. BENNETT AND CHARLES H. COLES.



Hayden Planetarium-Grace Eclipse Expedition.

A FREAK PHOTOGRAPH OF THE ECLIPSE

THIS UNIQUE UNRETOUCHED PHOTOGRAPH, ONE OF A SERIES MADE BY THE HAYDEN PLANETARIUM-GRACE ECLIPSE EXPEDITION IS ONE OF THE OCCASIONAL FREAKS THAT OCCUR IN PHOTOGRAPHY. IT WAS MADE LOOKING NEARLY DIRECTLY WEST OVER THE LEFT WING OF A PAN-AMERICAN GRACE AIRWAYS AIRPLANE OVER THE COAST OF PERU AT AN ELEVATION OF 25,000 FEET, A SECOND OR TWO BEFORE TOTALITY OF THE SOLAR ECLIPSE OF JUNE 8. ALTHOUGH ONLY A POINT OF DIRECT SUNLIGHT WAS STILL VISIBLE, THIS WAS SUFFICIENT TO ENTER THE CAMERA LENS AND CAUSE THE CENTRAL SPOT OF LIGHT WHICH APPEARS IN THE PRINT TO BE THE COMPLETE DISC OF THE SUN, AND TO FORM IN ADDITION (THROUGH REFLECTION BETWEEN THE SEVERAL SURFACES OF THE CAMERA LENS) A SERIES OF CIRCULAR RINGS ON THE NEGATIVE. IN THE FOREGROUND, 22,000 FEET BELOW, THE LAST BIT OF SUNLIGHT IS SHINING ON A CLOUD BANK 3,000 FEET OVER THE OCEAN. THE MANY OTHER PICTURES OF THE EXPEDITION, THOUGH LESS SPECTACULAR THAN THIS, HAVE MORE SCIENTIFIC VALUE. (PHOTOGRAPHED BY MAJOR ALBERT W. STEVENS.)

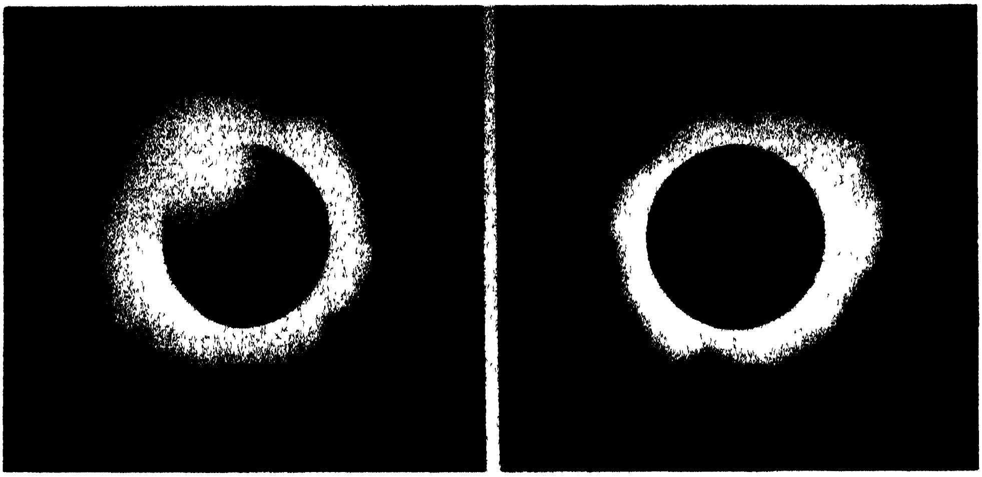
inner corona around the dark shadow of the moon and the last rays of the sun on one side shining through some valley or between some irregularities on the surface of the moon. The large solitaire of the "ring" was seen to break fleetingly into two small jewels before giving place to the outer corona.

The rays and streamers of the outer corona, extending for nearly two solar diameters into space, were of approximately the same length in all radii of the sun. This was due to the high incidence of sun-spots, three large groups having been observed on the day of the eclipse. During a minimum sun-spot period, the polar streamers are short, while the equatorial rays are very long.

Just at "second contact," the ridges of the prominences appeared in six different places along the moon's edge. Two grew and changed, rising and weaving as they swirled up to a full tenth of the sun's diameter.

Another "diamond-ring" appeared at the end of totality. Casting strange shadows, the partially eclipsed sun set in the ocean, the tips of the crescent pointing upward.

C. P. K.



Hayden Planetarium Grace Eclipse Expedition

STAGES OF THE ECLIPSE

Left, a "diamond-ring" photograph of the eclipse of June 8, made just ten seconds before the moon completely covered the sun. Right, total eclipse of the sun of June 8. The corona in the "diamond-ring" appears unusually wide in spite of short exposure and is due to the fact that the photograph was taken in rarefied atmosphere some 15,000 feet above sea level (Photographed by Professor William H. Barton, Jr)

WOODS HOLE CONFERENCE ON THE PROBLEMS OF AGING

The Union of American Biological Societies is interested in the promotion of activities which will tend to focus the somewhat divergent interest of its member societies on specific problems of fundamental importance The common feature of all member societies is that they are concerned in the investigation of living things. All these have a cycle of youth, maturity and old age The problems of growth, the upswing of the curve of vital processes, are being energetically attacked with adequate financial support. Those of aging, the downswing of the curve resulting inevitably in death, are on the contrary shamefully neglected We are all agreed that the problem of aging demands attention, and it does so more insistently as the average age of the population increases with improved food, living conditions and medical care. There is, however, little agreement as to the particular aspects of the problem which are of strategic importance and for which we have methods likely to yield worth-while results. Moreover, the data already available have not been collected and pieced together in such a way as to give a clear view in outline of the problem in its entirety. A survey, preliminary to the organization of research on a large scale, is therefore indicated

The union is not at present concerned with economic and social consequences of aging, important though they undoubtedly are, but with the biological and medical aspects of the processes of aging Since, as we have intimated, aging is a feature in the life of all organisms, this information must be gathered broadly from many forms in addition to man. Consequently, the Union, in fulfilment of its integrative duties in the biological sciences, sponsored a conference on the problem viewed from these angles held at the Cape Codder Hotel, Woods Hole, Mass., on June 25 and 26. The Divisions of Medical Sciences, Biology and Agriculture and Anthropology and Psychology of the National Research Council cooperated. The expense of the conference was defrayed by a grant from the Josiah Macy, Jr., Foundation. Those attending the conference were: A. J. Carlson,

MEMBERS OF THE WOODS H([illegible] FERENCE ON ...

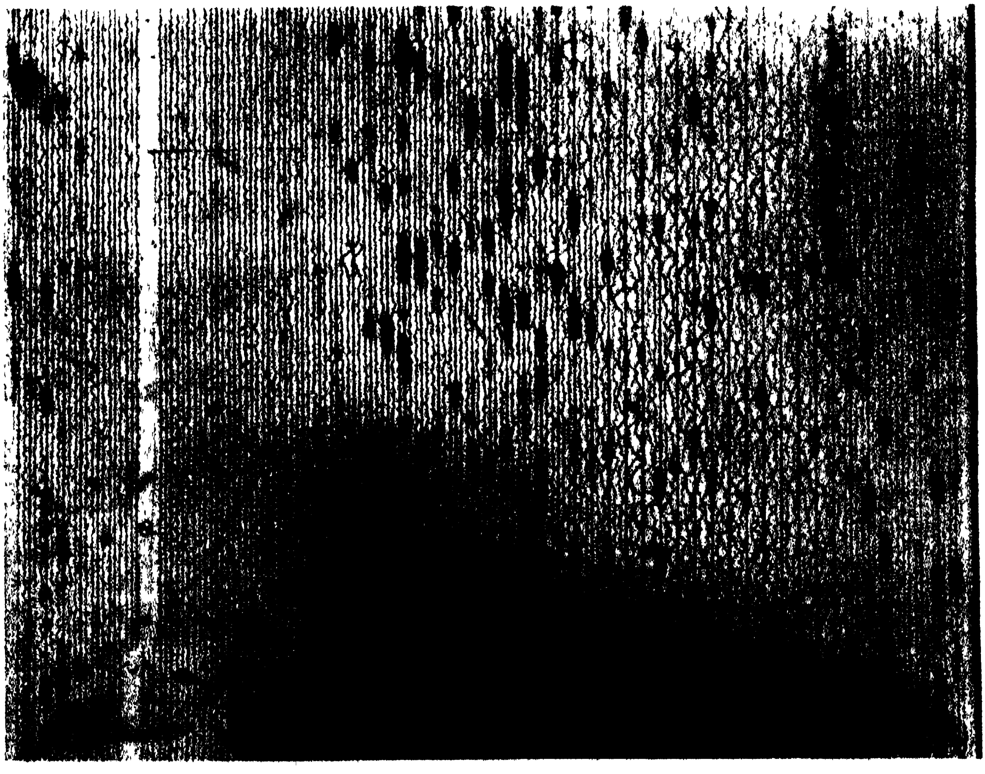
Which convened at the Cape Codder Hotel on June 25 and 26, und chairm Dr. ry. Standing, left to right: Dr. Jean Oliver, (Pathology) Stanford University Medical School; Valter R (Psy gy) Yale University; Dr. C. M. McCay, (Animal Husbandry) Cornell University; Dr. A. J. Car (Physiol ivers Chicago, Dr. F. Fremont-Smith, Medical Director, Josiah, Macy, Jr., Foundation; Dr. Earl Theron Engle, College c ians urgeons; Dr. Lawrence K. Frank, Assistant to the President, Josiah Macy, Jr., Foundation; Dr. Jonas S. Friedenw s Ho Medical School; Dr. Clark Wissler, (Anthropology) American Museum of Natural History; Dr. T. Wingate Todd my) rn Reserve University School of Medicine; Dr. Wm. de B. MacNider, (Pharmacology) University of North Caroli Alfrei John, (internal medicine) Rockefeller Institute; Dr. Alfred Friedlander, Dean of the School of Medicine, Univ Cinc ti; Dr. Louis I. Dublin, (Statistics) Metropolitan Life Insurance Company. Sitting, left to right: Dr. H. S. J (Zool , The Johns Hopkins University; Dr. W. S. Hunter, (Genetic Psychology) Clark University; Dr. Elmer ri) Harvard University; Dr. E. V. Cowdry, (Cytology) School of Medicine, Washington University; Dr. E. B. Kru , (School of Medicine, University of Pennsylvania; Dr. William Crocker, Boyce-Thom sti ant Research.

Alfred E. Cohn, E. V. Cowdry, William Crocker, Louis I. Dublin, E. T. Engle, Lawrence K. Frank, Jonas S. Friedenwald, Alfred Friedlander, W. S. Hunter, H. S. Jennings, E. B. Krumbhaar, C. M. McCay, Wm. de B. MacNider, E. D. Merrill, Walter R. Miles, Jean Oliver, F. Fremont-Smith, T. Wingate Todd and Clark Wissler. They include representatives of the union, the council, the foundation, contributors to a book on aging being prepared by the foundation and other interested persons.

E. V. Cowdry,
Chairman of the Conference

CEREBRAL STATES DURING SLEEP AS STUDIED BY HUMAN BRAIN POTENTIALS

If small metal electrodes are fastened to the scalp of a person, connected with a high gain amplifier, and the resulting electrical potentials observed or recorded, it is found that regular rhythmic changes in potential occur of five to several hundred microvolts amplitude and one to .03 seconds duration They come from the cerebral cortex and give us an objective method of investigating activity of the brain. The most interesting and best known of these rhythms has a frequency of about 10 per second and is called the alpha rhythm It is affected by vision, emotional states, sleep and many other conditions It is most apparent in some



BRAIN WAVES DURING SLEEP

SECTION OF AN EIGHT-HOUR RECORD DURING A NIGHT'S SLEEP. THREE PENS RECORD POTENTIALS FROM THREE DIFFERENT PARTS OF THE HEAD, ONE PEN FROM AN AMPLIFIER TUNED TO 14 PER SEC. RHYTHM, SHOWING VERY CLEARLY THE "SPINDLES." FROM LEFT TO RIGHT THE STATES PASSED THROUGH ARE C, B, C, D AND C. THE MARKED HIGH FREQUENCY POTENTIALS IN THE UPPER RIGHT-HAND CORNER ARE DUE TO MOVEMENT OF THE SLEEPER. DOTS AT LEFT-HAND EDGE OF FIGURE MARK SECONDS.

persons lying quietly with eyes closed and immediately disappears if the eyes are opened to view an object.

A series of over 200 records with 70 individuals of all ages has demonstrated that these potentials of the brain recorded from similar positions on the scalp of normal persons differ greatly in pattern Two types of individuals, with every possible intergrade, can be distinguished; at one extreme the type with almost continuous pure alpha (ten a second) rhythm; at the other the type with practically no alpha rhythm but with less regular higher frequency, so-called beta potentials One interesting case was observed of no alpha rhythm except for a few seconds after the eyes had been closed. This appeared whether the room had previously been lighted or was completely dark.

During sleep, the potential patterns change completely. They are so characteristic that they may be used as a criterion of states or depth of sleep. In a person showing continuous alpha rhythm we may distinguish the following states, described in the order in which they appear as a person sleeps: (A) *Interrupted alpha, i.e.,* more and more marked interruption of the alpha rhythm; (B) *Low voltage,* complete disappearance of the alpha activity with only low voltage changes of potential; (C) *Spindles,* the record slightly irregular, with short 14 per second rhythms or "spindles" every few seconds; (D) *Spindles plus random,* random potentials plus short bursts of 14 per second rhythm; (E) *Random,* the spindles become inconspicuous, but the large random potentials persist and come from all parts of the head.

The non-alpha type of person passes into the same states of sleep as the alpha type, but it is difficult to distinguish states A and B. State B is characterized by less high frequency potentials.

During a night's sleep or an afternoon nap, there is a continual shift of the person from one state to another. The changes are usually sudden, but may be gradual, especially from C to D and from D to E. There is no evidence of a continuous curve of sleep, although it is more difficult to wake a person in states D and E. The changes in state of sleep may be plotted against time and give a sleep record or hypnogram.

Movements may occur without any change in state of sleep, and a change in state of sleep may occur without movement, but occasionally the two are connected. After a movement the state usually changes upward and, when in the B state, alpha rhythm for a few seconds (A state) almost always occurs after a movement.

Stimuli or disturbances may shift the state of sleep suddenly. The shift is always upward, from one state to the next above, or one or two states may be skipped. Lack of a continued stimulus to which a sleeper is accustomed may act as a disturbance. Changes in state of sleep have been observed with no detectable external stimuli, but internal changes may be responsible. The ease of changing a state of sleep depends on which state the subject is in, changes appearing less and less frequently as the sleeper approaches the E level. These changes in state as the result of stimuli are frequently but not always accompanied by movement.

Finally, it must be emphasized that changes in pattern of brain activity after a stimulus are not the direct representation in the cortex of impulses from that particular sensory pathway but represent changes in state of cortical activity over wide areas. This is particularly evident in sleep. Thus a sound may result in the appearance of alpha rhythm for a few seconds, but we interpret this as representing a change in level of consciousness rather than a direct effect of the sound stimulus.

Evidence from two sleepers who awoke after dreaming leads us to believe that dreams occur in the B state but are not represented by any peculiar type of potential.

E. Newton Harvey
Alfred L. Loomis
Garret A. Hobart, III

THE SCIENTIFIC MONTHLY

SEPTEMBER, 1937

THE LIFE OF WILHELM CONRAD RÖNTGEN AS REVEALED IN HIS LETTERS

By Dr. OTTO GLASSER
CLEVELAND CLINIC FOUNDATION, CLEVELAND, OHIO

OVER forty years have passed since Wilhelm Conrad Rontgen, professor of physics at the University of Würzburg, (in 1895) saw the effect of a strange and unusual phenomenon while he was performing some experiments in his laboratory. This was the bright fluorescence of some barium platino cyanide crystals near an excited Hittorf tube He pursued the study of this effect in a most masterly and thorough manner, and discovered it to be due to "a new kind of rays" He called these rays "x-rays" This famous discovery, in addition to his other brilliant researches, placed Röntgen in the ranks of the world's "great men."

RÖNTGEN BUST IN THE MUSEUM IN LENNEP.

In his classic book on "Grosse Mäenner" Wilhelm Ostwald declares that the names of the great in the history of science should have a deeper significance than a mere association with particular data or discoveries which were contributed, for behind each of these discoveries there stands a man, perhaps one who did not tower noticeably above his fellows, who may have had to put forth a mighty struggle to attain his particular accomplishment. But many modern scientists and research workers evince little interest in the biographies of the great men who have preceded them, and for those who are anxious to know the personal, human side of their scientific forefathers, it often is difficult to obtain reliable information. In some instances, the man lived so long ago that the events of his personal life have passed into the limbo of a forgotten past, or perhaps he was shy and reticent during his lifetime, leaving little record except of his professional and scientific life. Such was true of Röntgen.

It is difficult to reconstruct a true picture of Röntgen's genius and personality. Since he had little to say about himself, it is not surprising that others said a great deal for him and of him that was not quite true, and that an amazing web of legend and fable has been woven about him and his discovery. At various times, I have made an attempt to unravel many of these fanciful tales. Although some are highly

WILHELM CONRAD RÖNTGEN

AT THE TIME OF HIS DISCOVERY OF THE "X-RAYS" (1895).

ingenious and full of romance and imagination, the fabrications in most instances can not be confirmed or even accounted for by a review of the actual facts and occurrences

When I began my studies on Röntgen, only a few scattered biographical accounts of him had been published, and most of these were written immediately after his death in 1923 to extol his virtues and the importance of his accomplishments. While such eulogies are motivated usually by a sincere and lofty purpose, they often do not present a true, unbiased picture of the man and his character. Hence, however much the great man may be admired, the conscientious biographer must try to expose to light the main facets of his personality, so that he may be seen somewhat as he actually was, rather than as an illusory image conjured up by the eulogist

There is no more true index of a man's character than his own utterances His conversations with friends, his publications, his speeches and, best of all, his personal letters show pretty well what manner of man he was Unfortunately, the writing of letters is fast becoming a lost art; but in Rontgen's day this was not the case, and he, himself, although shy and reticent in his personal contacts, was more articulate and communicative in his letters Both he and his wife kept in constant touch with their intimate friends and expressed themselves freely on a variety of subjects.

Although the letters do not contain a great deal of information concerning the scientist, Röntgen, they still permit many glimpses of his ideas about research work, as well as education in general, and these indicate the kind of scientist he was. According to Oswald, "The romanticist produces quickly and much, it is his first concern to finish the current problem in order to make way for a new one; the classicist is chiefly concerned with dealing with the current problem thoroughly and exhaustively." Röntgen was a typical classicist among scientists, and his attitude is well illustrated by a quotation from a lecture which he gave a year before he discovered the x-rays:

> Only gradually has the conviction gained importance that the experiment is the most powerful and the most reliable lever enabling us to extract secrets from nature, and that the experiment must constitute the final judgment as to whether an hypothesis should be retained or discarded. It is almost always possible to compare the results of ratiocination with practical reality, and this gives the experimental research worker the assurance his work requires. If the result does not agree with reality, it must necessarily be wrong, even though the speculations which led to it may have been highly ingenious

Röntgen again and again called attention to the fact that research work requires great mental effort and a great amount of time, that it necessitates keenness of observation and critical judgment and brings many disappointments In a speech made before his great discovery, he quoted almost prophetically from a book by the great engineer, Werner von Siemens, the following sentence.

> If some phenomenon which has been shrouded in obscurity suddenly emerges into the light of knowledge, if the key to a long sought mechanical combination has been found, if the missing link of a chain of thought is fortuitously supplied, this then gives to the discoverer the exultant feeling that comes with a victory of the mind, which alone can compensate him for all the struggle and effort and which lifts him to a higher plane of existence.

This attitude was expressed again when the enthusiastic students of the old Würzburg University honored Röntgen with a torchlight parade after his discovery. As he addressed the crowd assembled in the Pleicher Ring in front of the Physical Institute, he said:

> During the time when honors were showered upon me and unconsciously new impressions erased the older ones, there was always one thought that remained fresh and active in my mind, and that is the memory of the satisfaction which I have felt when my work was finally developed and completed. This is the joy derived from successful effort and from progress.

RÖNTGEN, RESTING IN CADENABBIA, ITALY, A FEW WEEKS AFTER HIS DISCOVERY.

Only a few Röntgen letters have been preserved which refer directly to the discovery of the roentgen rays Two of these letters, one written by Röntgen to his colleague, L Zehnder, and the other by Mrs Rontgen to their cousin, Mrs. Louise Röntgen-Grauel, in Indianapolis, are significant and, on account of their simple language describing the circumstances around the momentous discovery, might be called classics. The letter to Zehnder written shortly after the discovery reads.

Dear Zehnder

Many thanks for everything which you wrote me I cannot yet make use of your speculations on the nature of the x-rays, since it does not seem to me to be permissible or propitious, to attempt to explain a phenomenon of unknown nature with a to me not entirely unobjectionable hypothesis. Of what nature the rays are is altogether not clear to me; and whether they are actually longitudinal light rays is to me of secondary importance. The facts are the main thing In this respect my work has received recognition from many quarters. Boltzmann, Warburg, Kohlrausch, (and last but not least) Lord Kelvin, Stokes, Poincaré and others have expressed to me their joy over the discovery and their appreciation. That is worth a great deal to me and I let the envious chatter in peace, I am not concerned about that.

I had not spoken to anyone about my work; to my wife I mentioned merely that I was doing something of which people, when they found out about it, would say: "Röntgen seems to have gone crazy." On the first of January I mailed the reprints and then hell broke loose! The Vienna Press was the first to blow the trumpet of advertising and the others followed. In a few days I was disgusted with the business; I could not recognize my own work in the reports any more. For me photography was the means to the end, but they made it the most important thing. Gradually I became accustomed to the uproar, but the storm cost time; for exactly four weeks I was unable to make a single experiment. Other people could work, only I could not. You have no conception, how upset things were here.

I am enclosing the promised photographs; if you wish to show them in lectures it is all right with me; but I would suggest that you put them under glass and frame. Otherwise, they will be stolen.

How splendidly these words add to the importance of the classical first communication on the x-rays, and how well the following letter of Mrs Rontgen illustrates the effect on the Rontgen household of the sudden fame following the first reports of the x-rays. The letter was written on March 4, 1896, to Röntgen's cousin, Mrs Louise Röntgen-Grauel, who lived in Indianapolis and whose daughter kindly gave me the original.

Wilhelm has so much work he doesn't know which way to turn. Yes, dear Louise, it is no small matter to become a famous man, and few people realize how much work and unrest this carries with it. When Wilhelm told me in November that he was working on an interesting problem, we had no idea how it would be received, but as soon as his work was published, our domestic peace was gone. Every day I am astonished anew at the enormous working capacity of my husband, and that he can keep his thoughts on his work in spite of the thousand and one trivialities with which he is annoyed.

But I am speaking only of the less lovely part of our experiences and have said not a word about our great happiness over the success of his work. Our hearts are full of gratitude that we are permitted to live through such a wonderful experience. How many recognitions my dear has received for his tireless research. It would be alarming if the man who received all this were vain. But you know my honest, modest husband as scarcely any one else does, and you understand that he finds his highest reward in the fact that he was permitted to accomplish something valuable to Science.

In Röntgen's other letters, there is little mention of the discovery. Once many years afterwards, in 1921, when malicious gossip regarding the discovery was finding considerable credulence in certain quarters, Röntgen wrote to Mrs Boveri: "What do you think? Zehnder also has heard the fable that I was not the first to notice the x-ray but that an assistant

RÖNTGEN'S SUMMER COTTAGE IN WEILHEIM, NEAR MUNICH.

or a laboratory *diener* discovered them. What miserable envious souls must have invented this story? I must admit that these lies affect me a great deal more than they should.'' This statement by an essentially humble man proves his great honesty and dispels any doubt as to the actual circumstances of the discovery

As Mrs. Röntgen's letter shows, in spite of all the honors heaped upon him, Röntgen remained shy and retiring. The best expression of his modesty perhaps is to be found in his refusal to accept the personal nobility which was associated with the bestowal of the Royal Bavarian Order of the Crown. On June 13, 1896, Röntgen answered a letter from an official who had addressed him as Professor Doctor *von* Röntgen as follows:

> **In regard to the prefix *von* which you used in connection with my name in your letter of June 4, I should like to say that the paragraph of the rules of the Bavarian Order of the Crown referring to this states· ''The decoration of citizens with the Order of Merit of the Bavarian Crown includes the bestowal of personal nobility, as well as the use of the prefix of nobility, *von*, and can be exercised only after matriculation has been accomplished. Failure to make application for matriculation means forfeiting the rights of nobility.'' Since to date I have not made such application and since I am not intending to do so, I am not entitled to the use of the prefix *von*. Accept the expression of my sincere esteem. Dr. W. C. Röntgen**

With the same humility he declined to accept many highly flattering invitations to speak before various societies One of the few he did accept was an invitation to Stockholm to receive the first Nobel Prize for physics When he returned from that trip he told his colleagues ''The greatest and most satisfying joys the scientist can experience, no matter what problems he may be studying, are those derived from unprejudiced research Compared to the inner satisfaction over a problem properly solved, any outside recognition becomes meaningless ''

RÖNTGEN (CENTER) WITH MEMBERS OF HIS FAMILY (ABOUT 1865).

Naturally, to men of smaller minds and spirits, this idealistic attitude toward his work was difficult to comprehend, and many, motivated by jealousy or lack of knowledge, tried to minimize the importance of his accomplishments. The same intellectual honesty that characterized his attitude toward his work was evident in all his actions, and he had little patience with lesser men in the university who were actuated by selfish, personal motives or with those whose personal prejudices interfered with what Rontgen regarded as the welfare and future progress of science or the institution in which he worked He had numerous conflicts with his colleagues in Munich over such matters, as shown in a number of his letters to his good friend, Theodor Boveri. Once he wrote: "So many things could be beautiful and good in Munich if there were not some people who are chiefly convinced of their own importance!"

Röntgen could be gruff, and even rude, when he was aroused by disagreement over such matters, and he was particularly contemptuous of those who were inclined to gild superficial knowledge with brilliant rhetoric. "Physics," he said once, "is a science which must be wooed with honest effort. One can perchance present a subject in such a manner that an audience of laymen may be convinced erroneously that they have understood the lecture But this means furthering a superficial knowledge which is worse and more dangerous than none at all "

The same thoroughness was carried

RÖNTGEN WITH FAMILY AND FRIENDS IN THE SWISS ALPS NEAR PONTRESINA. FROM LEFT TO RIGHT: MRS. VON HIPPEL, PROFESSOR VON HIPPEL, PROFESSOR BEER, MRS. ZEHNDER, MRS. VON HALLER, RÖNTGEN, PROFESSOR ZEHNDER, BARON VON HALLER, MRS. RÖNTGEN, AND RÖNTGEN'S NIECE, BERTHA (1894).

RÖNTGEN AND MRS RÖNTGEN

ON THEIR RETURN FROM PONTRESINA, STOPPING AT THE ACHENSEE, SWITZERLAND.

over into his teaching methods, and he tried to inculcate in his students the intellectual honesty and self-reliance that he believed essential to any scientist. He was intolerant of those who did not take to their studies in this spirit, and he always told his assistants: "Do not pamper the student, for it is useless. Let each find his own way out of difficulties."

Many of Röntgen's letters, especially those to Margret Boveri, when she was a young student, illustrate the great respect he had for the study of science, and his ideas and lively interest in various phases of education. When she wrote him that she had begun to study physics, he answered:

> The activity of the mind in the study of experimental science, and especially Physics, its not very complicated problems, the probability of reaching a valid solution, and finally the particular method of investigation—the experiment—all this is so very different from that mental activity which is necessary in studying languages or art, that it is very beneficial to learn to know both kinds. Physics is also of great service to you in another way: all living beings, therefore all human beings, and the latter especially in their early years, are endowed with the ability to make observations and to draw correct conclusions from them. This gift is often withered in youth because of too intensive application to too many educational subjects, and this is a great pity, because it is extremely useful and brings great satisfaction.

He was constantly reiterating the idea that the student himself should contribute something, no matter what, rather than that he should commit and absorb that which others had thought or written on the subject. Once when Margret Boveri wrote him that she had written a composition on Charles the Great, he asked her to send him the manuscript, and then wrote to inquire what source material she had used and under what conditions she had written the essay. After all these questions he said: "I hope that you understand me correctly. I am trying to find out how many of your own ideas you have put into the presentation Of course I mean the actual presentation, because the historical part is not so important in this connection.'' When she gave him this information, he went to the trouble to look up all the references she had used, merely to see how much original effort she had put into that particular assignment.

In writing to her mother regarding the girl's study of music, he stated:

> According to my humble opinion, the main emphasis in the musical instruction of a talented pupil should be placed on the teaching of technique and less on implanting the interpretation of the teacher It certainly may be of interest to learn several interpretations, but the essential interpretation and its reproduction, even though it may be teachable, should be the individual effort of the pupil

All these illustrations show that Röntgen's ideas on education and his own intellectual habits agree remarkably with those advocated by modern educators and psychologists, for throughout his writings may be found innumerable evidences that he stressed accuracy, intellectual honesty, open-mindedness, suspended judgment, search for true cause and effect and critical judgment, including self-criticism.

The human side of the man, Röntgen, his warm feeling for his friends, his loyalty and interest in them under all circumstances, and his love and devotion to his wife are constantly revealed in his letters. His wife was ill for a number of years, and he cared for her and nursed her devotedly. After her death, he frequently referred to his loneliness and sadness at the loss of her companionship. On her birthday, the year after her death, he wrote to Mrs Boveri:

> Then I reread the letters of condolence which I had received after my wife's death. This was a somewhat sad, yet inspiring occupation. For again I saw how many different kinds of people understood my wife, and how much love and kindness she had earned, and so I ended the day peacefully.

The letters which Röntgen exchanged with his good friends revealed the many interests that they shared, for they abounded in discussions of scientific subjects, politics, vacations and recreations, nonsense and good humor, and the deepest concern over illnesses and other tragedies. Just before Boveri's death, Röntgen wrote him as follows:

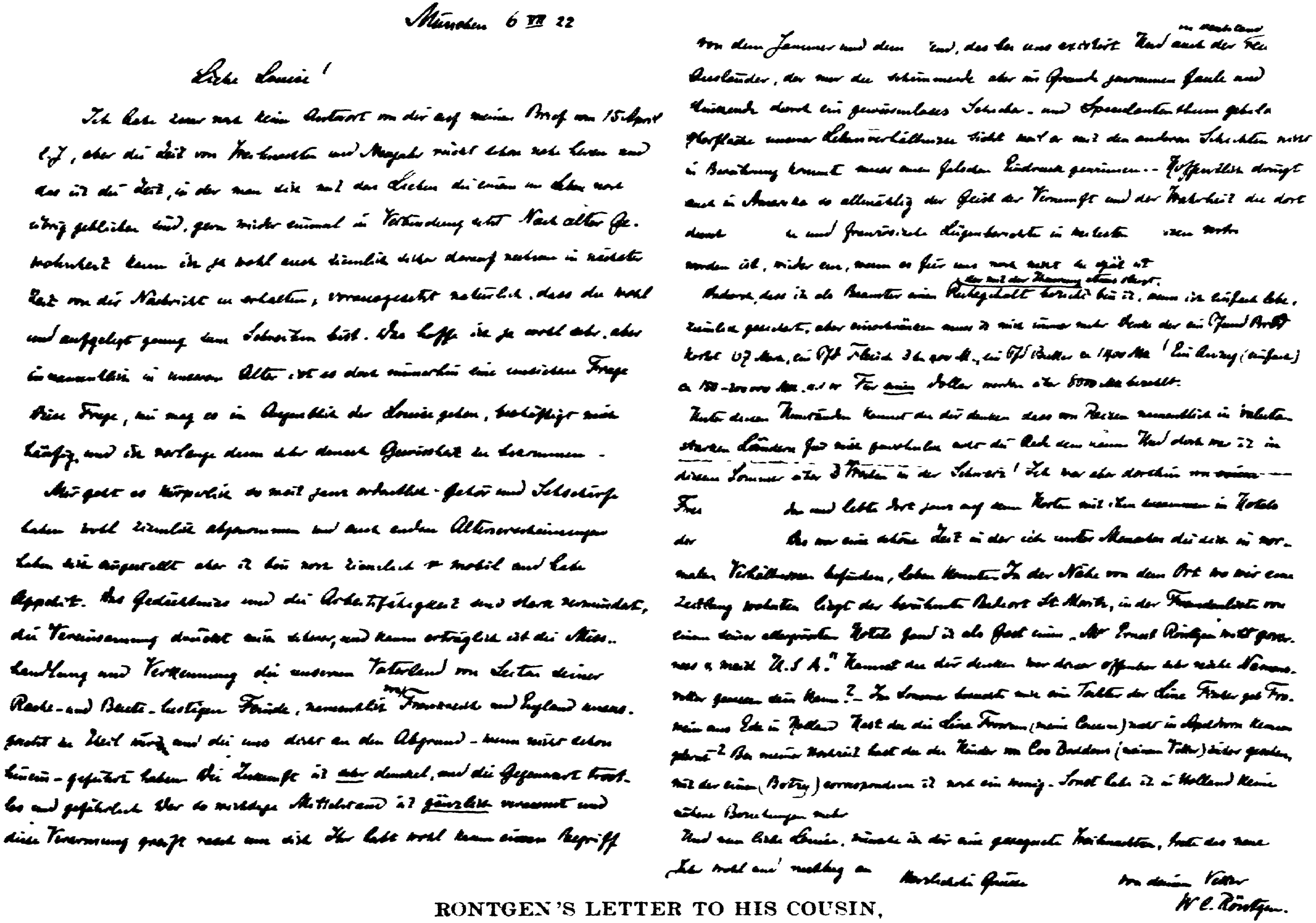
> *My dear friend*
>
> I found a bottle of sherry in my cellar and it is said that its contents are exactly as old as I am. At any rate, when I bought the bottle in Würzburg, the wine was fifty years old according to the label. I have sent you this contemporary of mine today with the hope that it will contribute its share toward making you feel stronger If it does that, then the ''old hermit'' will have done something useful

As long as the Röntgens were young and well, their letters radiated great good humor and the joy of living. They tell of vacation plans in Switzerland or Italy and contain congratulations for birthdays, Christmas and other holidays and anniversaries. Even when he was old, Röntgen frequently recalled some amusing incident from earlier days, which he would mention in his letters to his friends. Only six months before his death, in recalling some of the experiences of his early married life, he wrote:

> In Hohenheim there were rats in our house, and we were on very friendly terms with them. They got their daily food from the garbage in the kitchen sink. Aside from that they didn't disturb us. In our apartment in Strassburg we found bedbugs and cockroaches, but my wife soon exterminated them. We were young and could endure many an inconvenience with some good humor.

One of the chief joys of the Röntgens was their summer cottage in Weilheim and the hunting grounds which surrounded it. Hunting was a favorite pastime with Röntgen, and his letters abound in reference to this sport. His addiction to its joys are ruefully revealed in a letter written to Mrs. Boveri in 1921.

> My one sin against the hunting law came about as follows: According to my huntsman, a



RONTGEN'S LETTER TO HIS COUSIN,
LIS, WRITTEN WHEN HE WAS 77 YEARS OLD.
T IS TRANSLATED ON THE ADJACENT PAGE.

> deer with very good antlers frequently appeared, browsing in the meadows just where the footpath forms the boundary between Hirschberg's and my own hunting grounds. Often he came over my boundary and then returned. After our experiences during the last few years he probably would have been killed very soon by one of Hirschberg's huntsmen; many of my bucks have disappeared in this manner. As I sat yesterday on my hunting seat about fifty paces from the boundary, just as I was thinking about this, I saw the buck in a more favorable position than I would be likely ever to see him again, and in view of his beautiful antlers, I could not resist shooting May Saint Hubertus forgive me!

He was also very fond of other outdoor sports. In a letter describing his early student days in Utrecht, he said: "I went horseback riding, skating and indulged in other forms of physical exercise. *Mens sana in corpore sano* is the proverb, if my knowledge of Latin is still accurate" He was an excellent mountain climber, and even on his last trip to Switzerland, not many months before his death, he made long hiking trips through the mountains He described the joys of this experience in a letter written to his friend, Professor Wölfflin of Basel, when he was seventy-six years old.

> This is what I wanted to see once more before I die. The roaring mountain stream is for me the symbol of potential power. . . . One of the most beautiful episodes was the delightful trip from Tiefenkastel to Lenzerheide; there past

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MUNCHEN, December 6, 1922

Dear Louise.

I have not received an answer to my letter of April 15 of this year but now Christmas-time and the New Year approaches, and that is the time when one likes to get in touch again with those loved ones who are still alive As usual I can be rather sure to receive some news from you within the near future, provided of course that you are feeling well and are in the mood for writing. I hope that this is the case, but, especially at our age, this is very often uncertain. I frequently ask myself how you are and then I should like to know ———.

I am feeling rather well. My hearing and sight have decreased considerably and other signs of age have appeared, but I am still rather active and have a good appetite Memory and ability to work are considerably decreased and loneliness lies heavily upon me. The mistreatment and abuse to which our country is continuously exposed, especially on the part of France and England, is almost unbearable and has led us close to the abyss if not even into it. The future is very dark and the present is without hope and filled with danger. The great middle class is totally impoverished and this impoverishment is increasing rapidly. You probably have no idea of the misery and hardship which exist here. The foreigner who travels in Germany sees only the bright surface, of the fundamentally foul conditions produced by a conscienceless group of profiteers and speculating people and inasmuch as he does not get in touch with other classes he must gain a false impression. Let us hope that in America the spirit of truth and reason will gradually be victorious over the false English and French reports, which have been propagated widely, and I hope that that will be the case before it is too late for us.

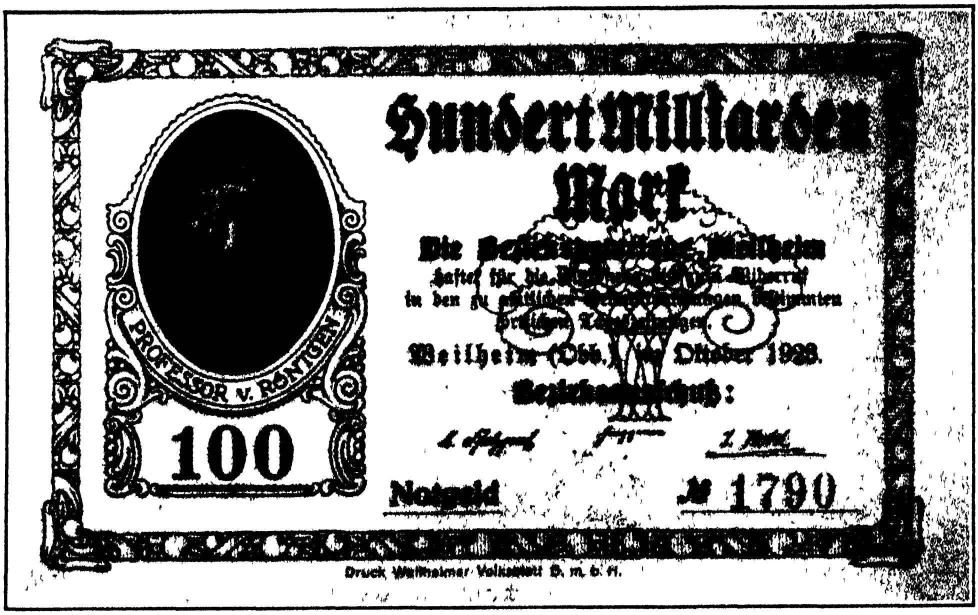
Since I am a government employee, I receive a pension which increases somewhat with the rise of prices of living and am thus relatively secure if I live moderately, but I must continuously practice more and more economy. Just think of it one pound of bread costs 67 marks; one pound of meat three to four hundred marks, one pound of butter about fourteen hundred marks and a simple suit of clothes about one hundred-fifty to two hundred thousand marks. For one dollar one can get eight thousand marks.

You can imagine that under these circumstances I ordinarily cannot travel in countries that have a high exchange rate, but still I was able this summer to spend three weeks in Switzerland. That was a wonderful time! During this time, I was with people who live under normal conditions. Close to the place where we stayed for some time there is a famous bathing resort, St. Moritz; in the guest list of one of its greatest hotels I found a "Mr. Ernst Roentgen with Governess and Maid, U.S.A." Do you know who this apparently very wealthy namesake could have been? Last summer a daughter of Line Fischer, nee Frowein, from Ede in Holland came to see me. Did you not meet this Line Frowein (my cousin) in Apeldoorn? At my wedding you no doubt met the children of Coo Boddens (my cousin). I still have some correspondence with one of them (Betry). Outside of that I have no connections any more in Holland.

And now, my dear Louise, I wish you a very Merry Christmas, begin the New Year in good health and with courage. Sincerest regards,

your cousin,

W. C. RÖNTGEN



INFLATION MONEY WITH RÖNTGEN'S PICTURE, ISSUED IN WEILHEIM.

> and present were united in one brilliant event. . . . I still prefer to leave the well worn paths and to hike over stick and stone I told Ritzmann if ever I should be missed not to look for me on the main road.

Both Rontgen and his wife appreciated beauty in all its forms. In German, we would call them *Lebenskuenstler*, artists of life. They derived much pleasure from music, art, literature, flowers, mountains and woods, and in many letters there are expressions of exuberant enthusiasm for some lovely thing They both enjoyed music and loved to have their musical friends come and play for them Once after attending the opera, Röntgen wrote. "How I enjoyed the Fidelio. Both overtures were played and Morena sang beautifully I was quite enthusiastic and carried away by the music. It is wonderful how soothing and refreshing music can be" Another time he said: "Bach's violin concertos are extremely lovely, and I only regret that I did not get acquainted with these beautiful things earlier" During his last year he wrote: "I enjoy rereading 'Don Quixote,' of which I own a very good edition. I learned again to love the two men, the Don and the Sancho, and enjoyed reading about their cleverness and their interesting characters"

Röntgen was very deeply affected by the fate of Germany in the world war, and his constant concern and interest in the affairs of the Fatherland are revealed in practically every letter written during the last ten years of his life. Although he had spent his early years in Holland and his college years in Switzerland, he had been born in the German Rhineland and his sympathies were all with Germany. At the outset of the war, he embraced the cause, heart and soul, yet he displayed relatively little of the psychosis of hatred so prevalent at the time on both sides, and he felt that many spheres of activity were influenced which should not have been affected at all by the prejudices engendered by the conflict. In December, 1914, he wrote to his friend, Hitzig:

We suffer much from the fact that the feeling in America, especially in the best circles, is strongly anti-German. I see in communications which I receive from learned men there that there exists such a lack of understanding of present events and conditions that one cannot help but ask how people who are ordinarily intelligent and reasonable can have such prejudiced opinions On the other hand, we also have professors whose behavior is unbecoming.

A few years later he wrote to Boveri·

The other day I received a pamphlet from a Belgian scientist which was somewhat embarrassing to me, especially because it referred to the well known proclamation of the ninety-three intellectuals which I, along with others, foolishly signed without first having read it, at the insistence of the Berliners.

Rontgen followed the events of the war with the most profound interest, and he foresaw with astounding insight many of the bitter consequences which ultimately eventuated Perhaps his contacts with relatives and friends in neutral countries enabled him to judge the actual situation more accurately. He was not blinded by prejudice or his emotions and was able to see the weakness in certain German institutions and practices In February, 1915, he wrote:

I do not feel that a quick decisive victory would have been a good thing for us. All of us should feel the seriousness of the war; this might protect us from danger and relieve us of several undesirable faults.

In November, 1918, as the war ended, he remarked:

That we in Germany have left the right path in our social life and that real love for our country has been replaced by a false pride and that we have become too materialistic—all that I told you long before the war, and I have discussed with you what seemed to me the only way to relieve this situation. However, I never would have believed, much less hoped, that we should have to suffer so intensely for our mistakes or that the medicine would come in such bitter doses. The conditions of the Armistice and the stipulations of peace which will probably be made are so depressing that it will be difficult to keep up enough courage to build up a satisfactory existence under the new conditions.

He displayed a fierce sense of justice, and was extremely bitter about certain events, such as the occupation of the Ruhr valley by French and Belgian troops after the war was over. "All our thoughts are constantly taken up with the infamous invasion into the Rhineland; because that is my homeland it gives me especial cause for alarm and indignation." This was written on January 26, 1923, a few days before his death

Although he was apprehensive concerning the outcome of the chaos in Germany's political affairs immediately following the war, he preserved his characteristic open-minded attitude in viewing the efforts of the new social democratic government He commented·

I also must say that all edicts and proclamations of the new Government are very reasonable It does not waste time in ordering changes in inconsequential matters In short, I feel that one may well expect from this government the best which can be hoped for. Of course, it is a question whether it can hold its own in the future, at least during the most difficult period of transition or whether ultraradical influences of Bolshevism may gain the upper hand. I believe with others that the latter danger is not imminent at the present time, at least not in Bavaria.

In view of the latest turn of events in Germany, one or two of Röntgen's letters have especial interest and significance There was a strong wave of anti-Semitic sentiment in the immediate post-war period, upon which he remarked on May 12, 1921, as follows:

The anti-Semitic incidents in Würzburg of which you write are exceedingly regrettable; it is not much better here. For instance, there is hardly an advertisement of rooms for University students which does not contain the statement, "No Jews," and I know of one instance when a woman said to a student who was looking at a room and mentioned his name, which sounded Jewish, "I do not take any Israelites." It is a bad sign of the times that decent persons can thus so rudely be insulted.

On the other hand, years before on December 27, 1906, he complained bitterly in a letter to Zehnder about the "Semitic impudence" of a colleague at the university.

I shall quote one more example of Röntgen's ability to look into the future almost prophetically. On January 26, 1923, he wrote a long letter to Wolfflin which contained a detailed discussion of the political situation in Germany and referred to the following incident:

> Martial law was declared in Bavaria yesterday and no public meetings are permitted without government permission. It is said that this regulation is directed against the National Socialists, who under Hitler—perhaps a second Mussolini (?)—caused some disturbance. I wonder whether it is not too late to lay the ghosts which have already been called forth?

In a short space one can not hope to give a complete picture of the character of a man like Röntgen, but in these few fragments snatched from his personal correspondence, there is perhaps some index of his outstanding characteristics. First among these was his absolute integrity in all things, in his work, his friendships and his attitude toward life, science and art. The deep seriousness of his nature was spiced with a love of fun, a sense of humor, an interest in sports and the outdoors which broadened his outlook and gave him a profound depth of understanding and almost prophetic vision.

RÖNTGEN'S HANDS.

THE KRUGER NATIONAL PARK OF THE TRANSVAAL

By Dr. MARY L. JOBE AKELEY

ADVISER, AKELEY AFRICAN HALL OF THE AMERICAN MUSEUM OF NATURAL HISTORY

ON a recent expedition in South Africa in 1935 and 1936, I visited the Kruger National Park of the Eastern Transvaal, which is generally conceded to be the greatest wild-life sanctuary in the world Here to-day there is without doubt a greater variety and concentration of wild life than in any other region of equal area on the entire globe. This preserve comprises an overwhelming majority of the African species.

For several years prior to this African journey, I had had the privilege of knowing in London the noted conservationist, Lieutenant-Colonel J Stevenson-Hamilton, who has been so largely responsible for the preservation of the vanishing fauna of South Africa. Chiefly through his efforts, not only have the remnants of the great game herds been preserved in sanctuary, but they have been so carefully guarded that the animals have increased—some of them to an astonishing degree.

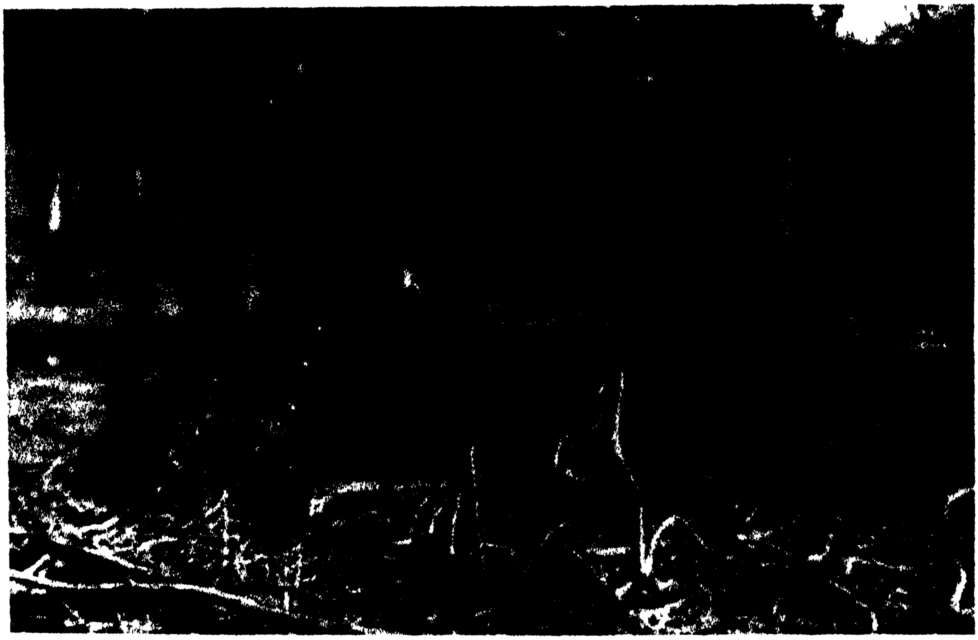
When the clouds of war were gathering above both the English and the Dutch in South Africa in 1898 the Sabi Game Reserve, the forerunner of the Kruger Park, was created It consisted of an area of 1,500 square miles in extent and included the lands lying between the Crocodile and the Sabi Rivers and immediately west of Portuguese East Africa. Here, at this time, were concentrated the last survivors of the varied and numerous fauna which once roamed over the greater part of South Africa, but which, with the advance of colonization, had been reduced almost to the point of extinction by the white man's gun or the native's spear.

From time out of mind until toward the close of the nineteenth century this once abundant and highly diversified fauna occupied vast areas between the Cape of Good Hope and the Zambesi. Antelope indigenous to the equatorial regions, as well as other African species peculiarly South African, lived in large and numerous herds in these wide and sparsely settled areas. Spreading across the rolling uplands even to the edge of the Kalahari Desert, great bands of springbuck afforded in their migrations a spectacle as amazing as the periodic journeys of our northern caribou herds. Elephants roamed to and fro across wooded hills where the City of Pretoria now stands. They were found in mighty herds in the lowlands along the Indian Ocean and on the High Veld, and from the Addo Bush to the jungle fastnesses of Portuguese East Africa. Giraffe, buffalo, hippos and black rhinos were plentiful; and the white rhino also was found in abundance from present-day Natal to the Western Transvaal. Among the wooded hills of the southern part of the continent the quagga (*equus quagga*) wandered about in bands so large that no one in that time dreamed that this handsome, vividly marked animal would to-day be exterminated. His cousin, the shy and graceful mountain zebra, now almost extinct as well, inhabited the rock-ribbed hills. Then there were other animals, equally abundant and rarely seen to-day: oribi, blesbuck, bontebuck and white-tailed gnu; and the true nyala, one of the most graceful and beautiful of all the African antelopes. Following stealthily along the trails of these great game herds were the carnivora—lions and leopards, cheetahs and wild dogs.

During the Anglo-Boer War great

changes occurred to the South African fauna. When the conflict was over, the only sanctuary found by these once-enormous herds of game was in the wild mountains and almost impenetrable bush country of the Eastern Transvaal. In 1902, when Colonel Stevenson-Hamilton was placed in charge of the Sabi Game Reserve, he found large areas without any game whatever. Along the Sabi River there were fairly large herds of impalla but almost no bushbuck, duiker or wart-hog. Among the larger antelope, only a very few greater koodoo, waterbuck, sable and roan antelope remained. Burchell's zebra and wildebeest were few indeed Buffalo and giraffe were almost extinct, numbering in each case only fifteen But the carnivora still persisted in numbers so great that it was difficult to understand how they could gain a living

A few years after the establishment of the Sabi Game Reserve, an area 6,000 miles in extent, south of the Olifants (Elephants) River, was added to the original tract. It was extremely wild, well-watered and better-stocked with game than any other region nearby. This tract had originally been surveyed and divided into farms by land companies in Johannesburg But lovers of wild life now brought great pressure to bear on the situation, to the end that these lands were annexed to the reserve. Fortunately for the wild creatures, hunting, too, had become unpopular throughout the country while the white population was engaged in repairing the ravages of war. A set-back was given to this great plan of conservation when Colonel Stevenson-Hamilton and his staff were called to the colors in the Great War. On their return from the battlefields of France, they found that poaching had become general, and that all the areas near the borders were a mass of traps and snares. Regularly organized native hunting par-



South African Railways and Harbours.

A CLOSE-UP OF AN IMPALLA

ONE OF THE MOST GRACEFUL OF ANTELOPES. THESE CHARMING CREATURES CAN COVER FORTY FEET IN ONE BOUND.

Copyright by Mary L. Jobe Akeley.

THE RARE GREATER KOODOO

WHICH SO FAR AS IS KNOWN HAS NOT BEEN PREVIOUSLY PHOTOGRAPHED BY AN AMERICAN.

South African Railways and Harbours

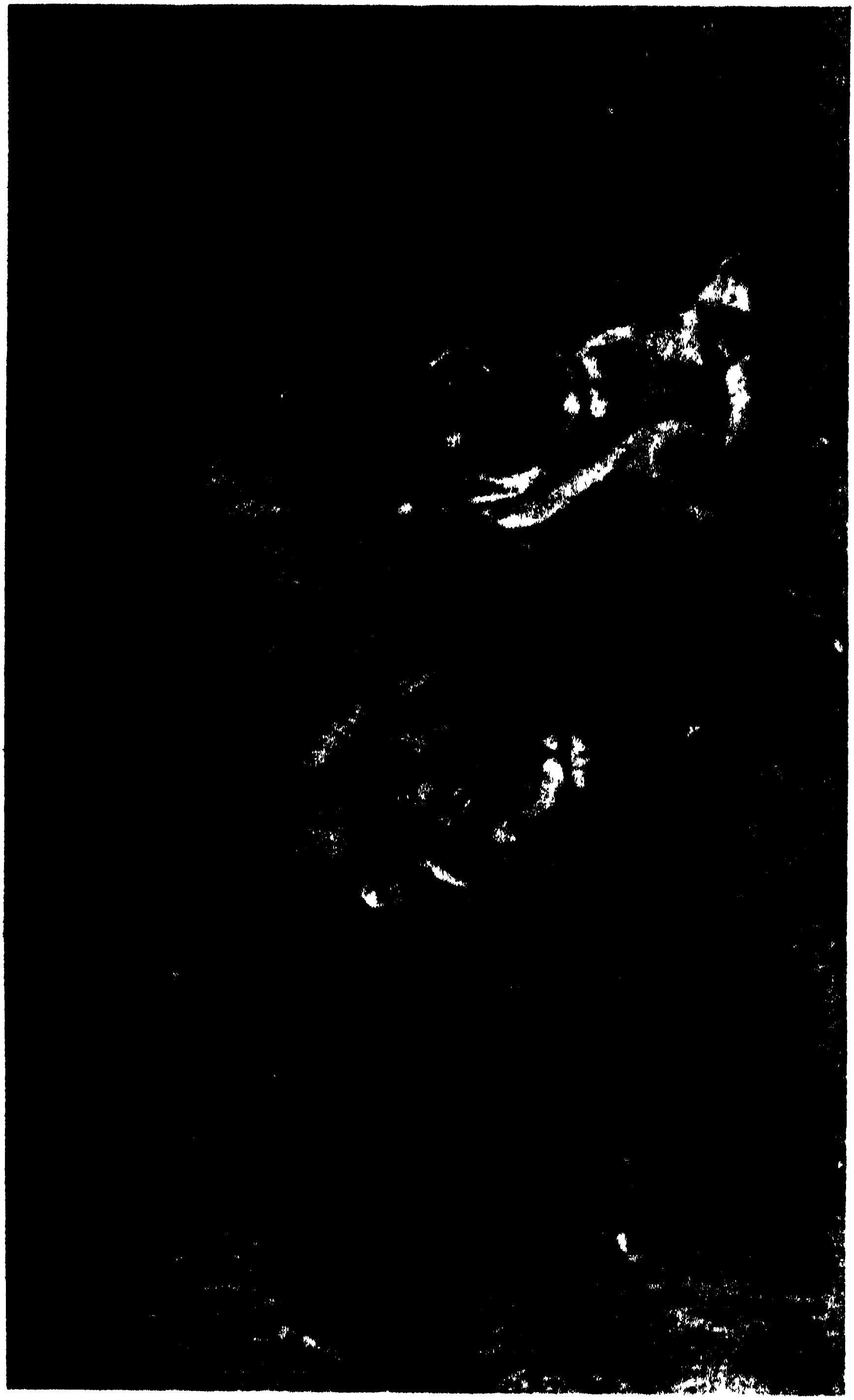
THE AFRICAN ELEPHANT

MANY HAVE TRAVELED IN FROM PORTUGUESE EAST AFRICA AND HAVE FOUND SANCTUARY IN THE KRUGER NATIONAL PARK

ties invaded the center of the reserve, where they camped for weeks, killing off the antelope, both large and small, which they converted into *biltong* or smoked meat. It was indeed a serious task which faced Colonel Stevenson-Hamilton. He now determined to control the Transvaal natives, as well as the Portuguese poachers. Finally, in 1922, popular sentiment became thoroughly aroused in favor of the animal sanctuary. The South African railways planned one-day excursions into the southern section of the reserve, in order to allow the passengers to view the game. The general public straightway manifested a tremendous interest in the preservation of wild life; and the national-park idea quickly and firmly took definite shape. Finally in 1924, when the grand-nephew of President Paul Kruger became minister of lands, the Kruger National Park (which as the Sabi Game Reserve President Kruger had first conceived) became a certainty; and in 1926 it was formally established.

Colonel Stevenson-Hamilton has held consistently to two ideals. The first was to reconstruct, in an area comparatively easy to police, the old life of Africa as it was before the onrush of the white man's civilization. This he has accomplished with amazing rapidity. Starting as he did less than fifteen years ago, he has seen a very scanty and timid fauna increase and become fearless of man, as he travels back and forth at slow speed in a motor car. Where until recently there were only grass lands and thornbush—desolate save for an occasional prowling lion or hyena—now there are large herds of antelope grazing peacefully and without fear of the hunter's gun. One might easily imagine that the impossible had occurred, unless the rapid breeding of these creatures when undisturbed in their natural environment were clearly understood. To-day the Low Veld is literally swarming with the antelope which were so near extinction when Colonel Stevenson-Hamilton took up the fight for their protection. He has undeniably won his battle.

Colonel Stevenson-Hamilton's second ideal was to arouse the minds of the general public to a new way of thinking. For years, they had considered the game only as provender for the pot or as stimulating their enjoyment of a bloodthirsty



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JUNGLE ROYALTY

THE AUTHOR WAS HELD UP ONE EVENING FOR TWO HOURS WHILE OUT IN THE JUNGLE BY THIS PAIR OF MATING LIONS WHICH EFFECTIVELY BLOCKED HER ONLY ROUTE BACK TO CAMP.

sport. Now he wanted them to grasp the idea that a living creature is infinitely more interesting than a dead carcass, even though the latter has food value. This idea has finally and firmly, even if slowly, prevailed.

It was late winter, the end of August, when I reached this last stronghold of big game. The days were warm and sunny; the nights cool, and the rains had not yet begun. It is undoubtedly the best season in which to visit this wild-life sanctuary. The park area itself, 200 miles long and 50 miles wide, reaches from Rhodesia on the north to Swaziland on the south. It extends beyond the eastern spurs of the Drakensburg Range Here the great interior plateau known as the High Veld falls off suddenly toward the east into a veritable wilderness of rolling hills, which at a distance have the appearance of an almost-level plain High ridges and deep ravines are cut here and there by long rivers that make their way through the solitudes of the Lebombo Mountains to the Indian Ocean. This area is between 500 and 1,500 feet in elevation and is thickly clad in virgin bush. Table-topped acacias and dwarfed thorn trees cover the rolling plains, while wild fig trees, palms and vines crowd in a tangle along the water courses. Wild grasses thrive everywhere in the small open spaces, growing so dense and tall along the streams that they obscure equally well a pride of lions or a herd of buffalo.

It is by no means difficult to see the animals in the Kruger National Park Every part of the reserve may be visited by making one's headquarters in the comfortable rest camps situated only a day's journey apart and connected by well-made roads.

Among the most astonishing sights in the park are the herds of impalla. Here, almost any day, along the lower Sabi, you can see herds of one or two hundred of these graceful tawny creatures. Their rate of increase is so great that, although many are killed by lions, yet there is no apparent depletion in their ranks When the visitor approaches, these delightful animals as a rule will remain quietly feeding or else will pause only to gaze at the oncoming motor car. Usually they give ground quite casually. Only when acutely disturbed do they take to sudden flight. Then, in a wild stampede, they will clear the ground in leaps and bounds, vaulting sometimes 20 to 30 feet in the air.

The most glorious animal I saw in the park is the greater koodoo. To me, no creature in the wilds excels a mature koodoo bull in beauty and dignity. As he stands with his exquisitely modeled head held high, his tawny-gray coat brilliantly striped in white and his crown of spiral horns shining in the sun, he is the epitome of grace, strength and grandeur.

A close second to the greater koodoo, if not his equal in distinction, is the sable antelope. He is even more rare and extremely difficult to photograph. The sable bull is strikingly marked. His body is black, shading to brown, and he is almost pure white underneath. His horns are long and formidable, highly arched and sharp as a saber. The female is rufous, and the calves are a somewhat lighter shade. As the sable bull sweeps across the veld, holding his head high, he appears noble, fierce and courageous. His long saber-like horns, the finest weapons carried by an antelope, are so effective that he has nothing to fear from any enemy save the lion, or from one of his own kind when during the mating season the bulls engage in deadly combat. One of the rangers told me that when the sable fights he swings his long curved horns back and forth with startling rapidity, guarding the entire length of his powerful body, one side after the other; and that it would be next to impossible for any enemy to attack him in his position unless similarly equipped. Colonel Stevenson-Hamilton says that he has never found a full-grown sable bull killed by any of the carnivora except lions; and that only one attack of wild dogs upon a sable was ever witnessed by any of his staff. In captivity, the sable bull usually becomes exceedingly vicious and dangerous; but in the wild state, notwithstanding his courage and power as a fighter, he is never aggressive to man. I was fortunate indeed to photograph, now and then, two or three sable bulls that were ranging apart from the herd; and on one occasion I secured a film of a herd of nine, consisting of bulls, cows and calves less than half grown

Standing next to the koodoo and sable in size and importance is the water-buck found along all the large rivers. I saw them frequently, in bands of five or six, swimming and wading in the streams or grazing in the grass lands along the shores.

The giraffe herds of the park have now increased remarkably, and in the north-central section they occur in great abundance. Here, ever gentle and appealing in aspect, and only slightly disturbed by the approach of a motor car, they are comparatively easy to photograph. Now and then they posed for me in groups of ten or twelve; and on one occasion I photographed two young giraffe as they cropped daintily at a thorn bush, quite out in the open and not more than 15 feet from my camera.

One morning I had a fine view of seven tsesseby, said to be the swiftest of all the African antelope Here, they are rarely seen and are considered extremely difficult to photograph. The tsesseby is closely allied to the blesbuck and the bontebuck and is also related to the hartebeest. His nearest relative in equatorial regions is the topi, which has a much darker coat. Topi, like the tsesseby, are found in small bands and are extremely fleet of foot.

The most numerous of the antelope species in the Kruger National Park is

South African Railways and Harbours.

"SEA COWS"

AS THE OLD-TIMERS CALL THE HIPPOPOTAMUSES—ABOUND IN THE CROCODILE AND SABI RIVERS OF THE KRUGER NATIONAL PARK.

South African Railways and Harbours

WILDEBEEST AND BURCHELL'S ZEBRA

ARE ALWAYS FOUND TOGETHER IN THE KRUGER NATIONAL PARK.

the wildebeest They are found in small herds in almost every section of the park and are usually accompanied by the Burchell's zebra These animals, closely akin to the now-extinct *quagga*, are so socially inclined that rarely are they seen in isolated groups They are extremely shy, constantly on the alert and are said to act as sentinels for the wildebeest herds. Seldom will they face the camera longer than for a few seconds. The moment they sight an intruder, they will trot away for several rods, pause for a little while when quite out of camera range, and then vanish in the bush.

In addition to the antelope previously mentioned, there are bushbuck, reedbuck and duiker. Then there are a few steinbuck, delightful little creatures loving the open grasslands. They are usually seen singly, except in the mating season, when one pair only will travel together. They are timorous little animals and often are seen taking refuge behind a small bush or a tall bunch of grass.

Warthogs are abundant. Some of the males have extremely formidable tusks and are redoubtable antagonists. I heard of one instance in which a warthog boar attacked and killed a lioness

A large herd of elephants inhabits the densely forested areas around the Letaba River. Since the creation of the Kruger National Park, many elephants have traveled in from the unprotected areas of Portuguese East Africa and have found sanctuary in this great reserve. Now and then, they come so close to the ranger's stations or to the motor track that visitors to the park are warned by conspicuous signs—"Look out for the Elephant." The fifteen elephants existing in the Sabi Game Reserve in 1902 had increased to a hundred animals in 1922. The herds to-day are larger still, as in the past fifteen years they have been reenforced by other elephants from beyond the Lebombo Hills in Portuguese territory. The buffalo herds, too, have multiplied many times. To-day, several hundred buffalo range in the dense jungles along the lower Sabi River, while smaller herds are often seen near Crocodile Bridge.

Leopards and cheetahs also occur in the reserve. I was fortunate indeed to

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LIONS AND LIONESSES

ONE HOT NOONDAY THE AUTHOR SAW A LARGE FAMILY RESTING IN THE SCANTY SHADE OF AN ACACIA TREE.

photograph both of these animals in the light of day.

Besides the animals above mentioned, there are large troops of baboons. These are the chacma baboons, somewhat darker and larger and more sturdily built than the baboons found in East Africa. Often I saw these interesting creatures sitting about close together or feeding in a circle, while the little ones scampered about with one another in the center of the ring. Bands of vervet monkeys gamboled about among the larger trees along the rivers. They are very difficult to photograph, as they are grayish-yellow in color and quite inconspicuous against the gray tree trunks.

Here, too, there is no dearth of bird life. Bustards, francolins and especially guinea fowl are frequently met with. Waterfowl, too, are beginning to come into the sanctuary; knob-billed duck, shell duck and spur-winged geese. Saddle-billed storks, also, have been seen about the waterholes. Guinea fowl, which present the same appearance as our domestic variety, are so numerous that a flock of thirty or forty feeding in the open is a common sight. They are so unafraid that instead of running quickly to cover as they do in the unprotected zones, they take their own time about moving on. They are of the greatest benefit in destroying harmful insect life.

Perhaps the most interesting of all the animals in the Kruger National Park is the lion. Many visitors travel more than a thousand miles by motor car on their annual holiday with the chief object of seeing the king of beasts in his native haunts. Seldom are they disappointed; for here, where the antelope herds are numerous, the lion no longer has difficulty in solving his problem of existence. In the rest camps, lions frequently may be heard roaring in the night-time or in the very early morning. Shortly after dawn, it is comparatively easy to see a lion on his kill near the road on the lower

Sabi, where they abound. They pay little attention to man in his motor car and seldom take the trouble to seek the seclusion of the bush in order to enjoy their early-morning breakfast. Since it is especially desirable that lions should not associate a motor car with man, it is one of the laws of the park that no one leave a car for the purpose of photography.

I saw many lions under varying conditions, each of which portrayed a different chapter in their habits. One late afternoon I watched a mother teaching her two small cubs to kill. On early mornings I observed lions and lionesses stealthily stalking the game. One early evening I saw six lions patrolling a small pool of water, once a large swamp in which the grass and reeds grew high Herds of thirsty antelope, zebra and a lone bull giraffe marched up and down on the opposite bank of the drying marsh waiting for a chance to drink. I was told that these lions lay up in the dense vegetation of the swamp during the day and come out only at twilight or at dawn to kill For more than an hour I watched the thirsty herds approach the pool, then on getting the scent of the lions stampede back to the safety zone, while the lions kept up their watchful waiting At last twilight fell upon the scene and I was compelled to return to camp, but knowing full well that when the darkness fell the big cats would kill and feast.

On another occasion I was held up for more than two hours by a pair of mating lions I had made a wide detour about them through scattered bush, in order to photograph them in the best possible light. Then they had suddenly moved down to the edge of the donga through which I had come, where they effectually blocked my only route back to camp We tried every possible method to cause them to move from the spot they had chosen We shouted at them, tooted the motor horn and hurled chunks of wood at them; and finally as darkness overspread the veld we turned on our headlights But the lions took their own time in moving out of our way When at last the jungle lovers got up from the floor of the donga, climbed to the opposite bank and then moved a few feet away from the track over which we had come,

South African Railways and Harbours.

THE TRUE OR MOUNTAIN ZEBRA

NOW ALMOST EXTINCT, IS THE SMALLEST OF ALL ZEBRAS. NATURE LOVERS ARE FIGHTING TO PRESERVE THE FEW REMAINING SPECIMENS, WHICH ARE FOUND IN TWO VERY SMALL HERDS IN THE CAPE COLONY.

we were finally able to make our escape. I was then quite certain that I had seen enough of lions for that expedition at least.

The animals of the Kruger National Park are under the constant supervision of the warden, Colonel J. Stevenson-Hamilton, and his corps of able assistants, the rangers of the park. Each white ranger has a staff of native rangers assisting him in the patrol of his territory These rangers exercise tireless vigilance in their study of wild-life conditions in their domain. They are also equally on the alert for any enemy that might creep in from beyond the borders for the purpose of hunting In their faithful, watchful patrol of their own districts, they are frequently brought face-to-face with high adventure. Such supervision insures the welfare of the game The warden and his staff constantly study the conditions of food-and-water supply. They protect the wilderness against fire and assist, as far as it is humanly possible, in the preservation of the balance of nature This means that no species is allowed to preponderate to the detriment of others. For example, there must be counterpoise maintained between the carnivora and the herbivora. The big cats are not permitted to kill off the antelope to the point of decimating the herds and thus diminish their own normal food supply. On the other hand, if for any reason lions and leopards are reduced unduly by artificial means, then there is no salutary deterrent to the survival of the unfit. It has been proved beyond contradiction that it is most unfortunate biologically for any herd or family to harbor the decrepit and diseased. There can be no compassion for the aged in jungle law. One of the most serious tasks, therefore, of the warden and his staff is to keep these species strong and healthy, with power to increase normally.

As a result of my intimate study of the wild life of the Kruger National Park, I became not only completely fascinated by the natural beauty of a new land, but even more by this rare opportunity to study at close range the great game herds living under conditions comparable to those before the coming of the white man. Throughout my entire expedition I received invaluable help and great courtesy. To the Prime Minister, General Hertzog, to General Smuts, to the officials of the South African Railway, to Colonel J. Stevenson-Hamilton to the National Parks Board and to my many new-found friends in South Africa I owe an overwhelming debt of gratitude for their unfailing kindness, their hospitality and for their assistance so graciously and freely offered From the Hon. Ralph W. Close, South African Minister to Washington, and to the Hon Charles Te Water, South African High Commissioner in London, I received invaluable help in planning my expedition and to them also I shall ever be deeply grateful.

EARLY EVIDENCES OF INDIVIDUALITY IN THE HUMAN INFANT

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THERE is a popular impression that all babies are much alike, especially young babies. This impression has received some scientific support from those psychologists who hold that the behavior of infants is chiefly patterned through conditioning processes and through specific learning On the basis of the conditioning theory of development, individual differences at birth are slight and increase with age

Without pressing unduly the old issue of nature *versus* nurture, we may profitably investigate the question whether individual differences do or do not declare themselves early in life At the Yale Clinic of Child Development we have gathered data on the problem by periodic behavior surveys of normal infants, by clinical studies of defective and atypical infants, by comparative studies of infant twins, by biographic records of the feeding behavior of infants and by naturalistic cinema records of infants in the situations of everyday life.

The present report is based upon an analysis of the cinema records of five normal infants from homes with high average living conditions (Girl A, Girl B, Boy A, Boy B, Boy D, as delineated in "An Atlas of Infant Behavior") [1] These children were photographed under homelike conditions at lunar months throughout most of the first year. Extensive cinema records embraced the major events of the infant's day, namely sleep, waking, bath, dressing and undressing, feeding, play and social behavior at advancing age levels Briefer cinema records and psychological observations of the same children were made at the age of five years

A trained and unbiased observer, Mrs Louise B. Ames, who had never seen the infants and who knew nothing about them, undertook a detailed analysis of the cinema records covering the first year of life She made a summary of the behavior of each infant, at each month; and in each situation. On the basis of *the objective evidence of the films alone,* she made an estimate of fifteen behavior traits and arranged the children in rank order for each trait After this appraisal had been recorded, she made a direct study of these same children, now five years old, at their homes and at the Clinic. The behavior data at five years included an intelligence examination, performance tests and numerous observations of the social reactions of the children to strangers, to the photographic situation and to a tea party in which they participated. The observer made continuous stenographic notes.

After this follow-up study, the observer made a new appraisal of the original fifteen behavior traits Care was taken to make this an independent appraisal, uninfluenced by the previous ratings which had long ago been set aside.

With these two sets of appraisals it was possible to make a comparative study of the traits of behavior individuality at one year and at five years of age. This comparison became an experiment in prediction, because we were able to ask with respect to each trait, "Is its strength in the first year of life predictive of a similar strength in the fifth year, when the five children are compared?"

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[1] Gesell *et al.*: "An Atlas of Infant Behavior: A systematic delineation of the forms and early growth of human behavior patterns." Illustrated by 3,200 action photographs, in two volumes. New Haven: Yale University Press, 1934. Pp. 922.

The fifteen traits which were sufficiently objective to yield to clinical appraisal were as follows:

1. *Energy output* (general amount and intensity of activity)
2 *Motor demeanor* (postural bearing, general muscular control and poise, motor coordination and facility of motor adjustment).
3 *Self-dependence* (general self-reliance and self-sufficiency without appeal to the assistance of others).
4. *Social responsiveness* (positive reactivity to persons and to the attitudes of adults and of other children).
5. *Family attachment* (closeness of affection; degree of identification with the family group).
6. *Communicativeness* (expressive reference to others by means of gesture and vocalization).
7. *Adaptivity* (general capacity to adjust to new situations).
8. *Exploitation of environment* (utilization and elaboration of environment and circumstances in order to gain new experience).
9. *"Humor" sense* (sensitiveness and playful reactiveness to surprise, novelty and incongruity in social situations).
10. *Emotional maladjustment* (balance and stability of emotional response in provocative situations).
11. *Emotional expressiveness* (liveliness and subtlety of expressive behavior in emotional situations).
12. *Reaction to success* (expression of satisfaction in successful endeavor).
13. *Reaction to restriction* (expressiveness of

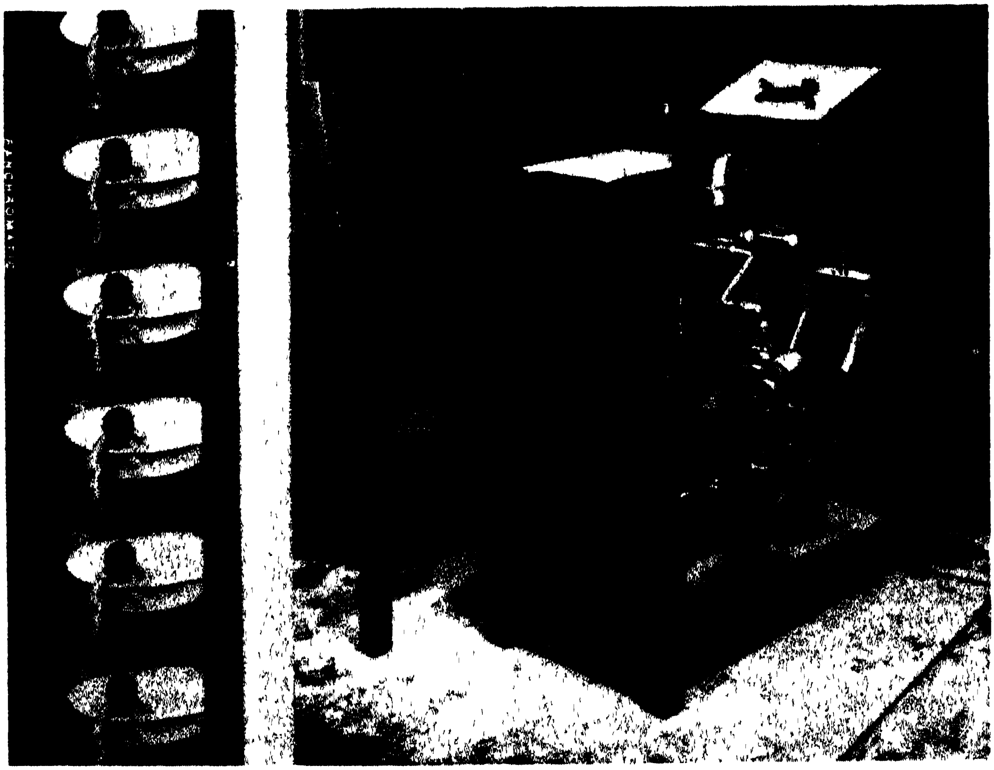

FIG. 1. THIS PRINT WAS MADE DIRECTLY FROM THE CINEMA RECORDS WHICH FURNISHED THE BASIC DATA FOR THE PRESENT STUDY. THE RECORDS DEPICTED THE EVERYDAY LIFE OF THE INFANT. THE FILMS WERE ANALYZED WITH THE AID OF A SPECIALLY DESIGNED PROJECTION DESK.

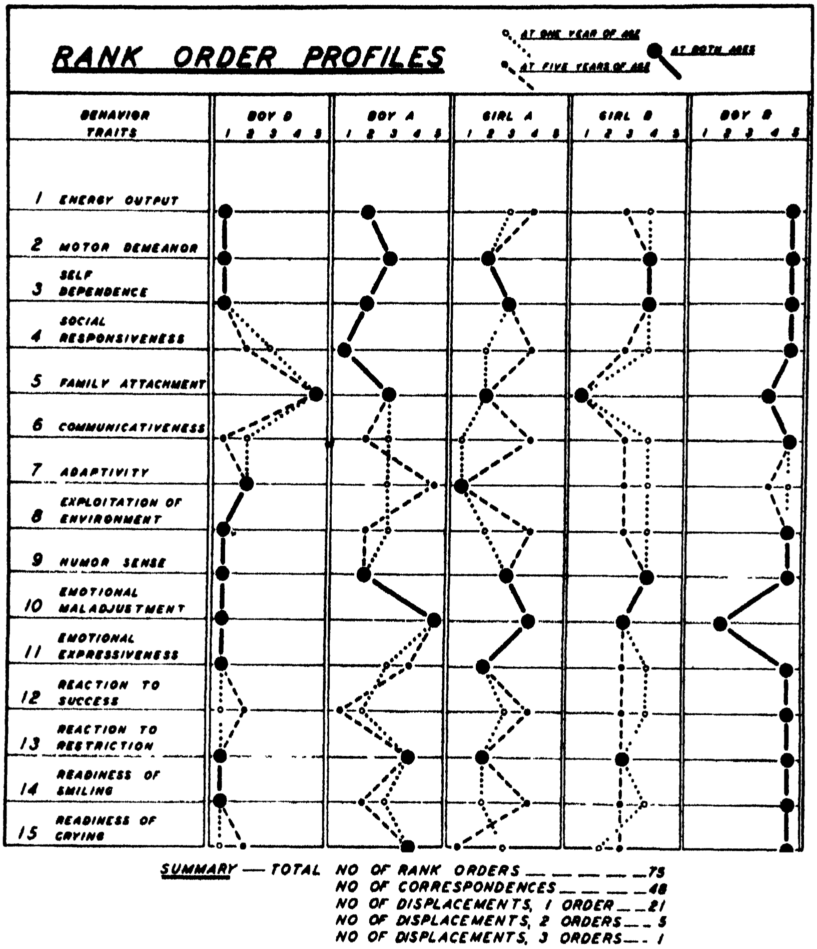

FIG. 2. THIS GRAPH PICTURES THE PREDICTIVENESS OF INDIVIDUALITY TRAITS AS APPRAISED IN INFANCY AND AT THE AGE OF FIVE YEARS. FIFTEEN BEHAVIOR TRAITS LISTED IN THE LEFT COLUMN ARE RATED FOR FIVE CHILDREN IN THE ADJOINING COLUMNS.

behavior in reaction to failure, discomfort, disappointment, frustration)

14. *Readiness of smiling* (facility and frequency of smiling).

15. *Readiness of crying* (promptness and facility of frowning and tears).

In spite of the fact that these categories to some extent overlap, it was found that they yielded to separate judgments based upon objective signs. Errors of judgment tended to remain uniform because they were made by a single observer. In every instance it was possible to assign with certitude the extremes of the rank order for the fifteen traits and for the group of five children Intervening rank orders were assigned by bringing the available data into systematic comparison.

The method of cinemanalysis favored a disinterested and objective approach to the basic data. By means of a movieola and a projection desk (see Fig. 1), it was possible to subject the extensive records of infant behavior to thoroughgoing scrutiny. Significant episodes were repeatedly viewed by slowing of motion or by frame-by-frame inspection. In the

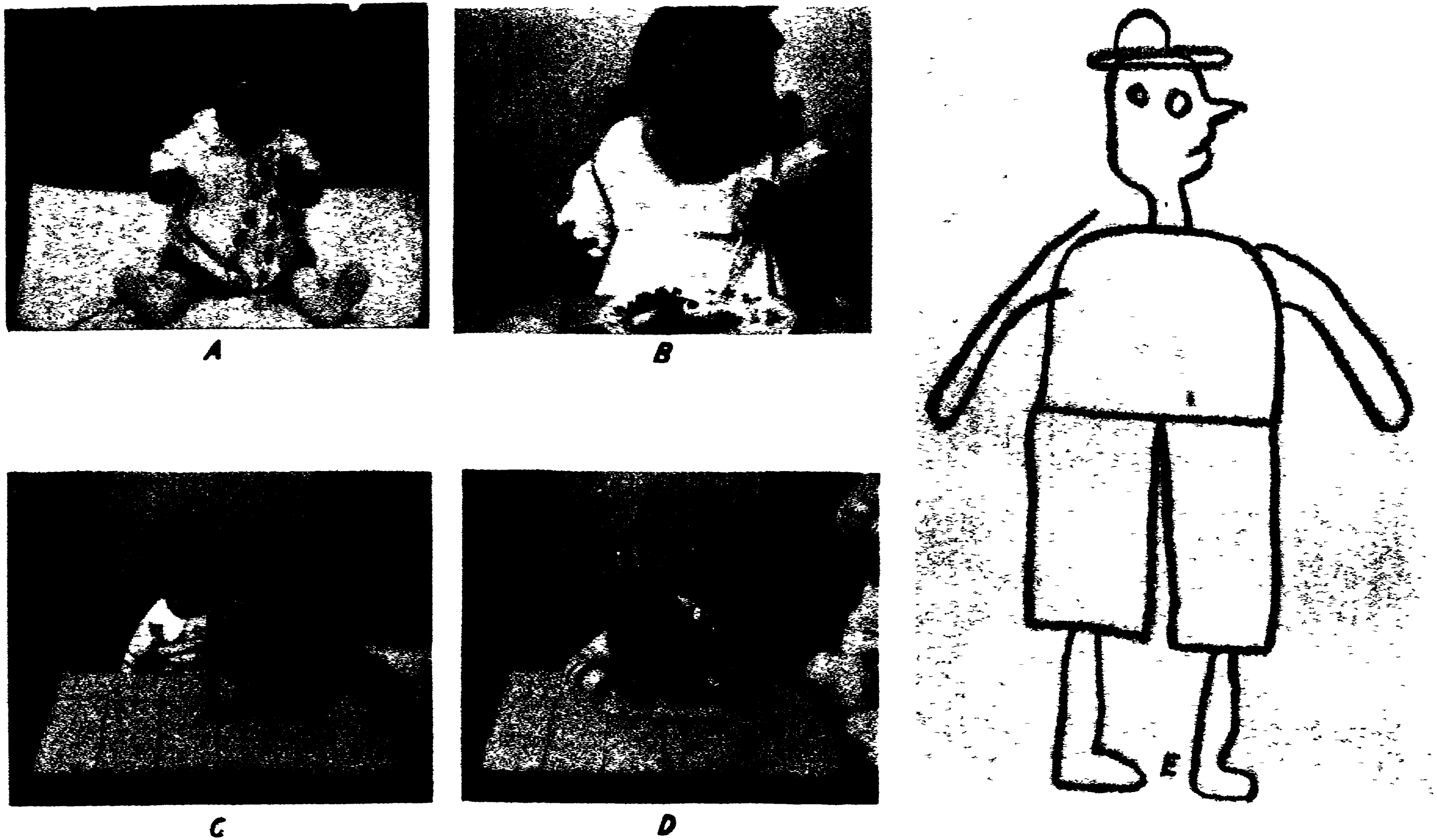

FIG. 3. A DEEP-SEATED MOTOR TRAIT OF INDIVIDUALITY.

THIS CHILD SHOWED PRONOUNCED LEFT-HANDEDNESS: (a) IN MANIPULATION (AGE 36 WEEKS); (b) IN SPOON FEEDING (AGE 80 WEEKS); (c) IN BLOCK BUILDING (AGE 260 WEEKS OR 5 YEARS); (d) IN DRAWING (ALSO AGE 5 YEARS). SHE DRAWS A LEFT-HANDED TYPE OF MAN PICTURED IN e field of locomotion the time values of the movements of members of the body were determined and computed for comparative purposes.

Cinemanalysis constitutes a unique method of observation, because it permits at will recurrent observation of events which in nature happen only once. The divisibility of the cinema records also permits a flexible manipulation of the data so that the recorded events can be brought into varied forms of comparison altogether impossible in actual life.

The method of cinemanalysis therefore proved to be admirably adapted to an impersonal treatment of personality data. It should again be recalled that in the present study the cinemanalysis was made by an investigator who had had no first-hand personal contact with the children whatsoever. On the basis of detailed and critically repeated observations an array of predictions was formulated. The behavior survey at five years was made with sufficient thoroughness to bring any serious errors of prediction to light.

The accompanying graph (Fig. 2) summarizes by profiles the rank orders for each of the fifteen behavior traits as assigned at one year and at five years. The heavy lines and large discs in these profiles indicate the items in which there was complete correspondence in the estimates made at the two ages. Dotted and broken lines indicate those instances in which there was a discrepancy between the appraisals at one year and at five years, respectively. Out of 75 judgments, 48 coincided; 21 showed a displacement to the extent of one rank order; 5, a displacement of two orders; 1, a displacement of three orders. The tendency was toward under-prediction. When the rank orders for each of the children are summated into grand totals, the correspondence in the net appraisal ratings at one year and at five years proves to be close: Boy D, 23, 23; Boy A, 43, 42; Girl A, 35, 45; Girl B, 53, 45; and Boy B, 71, 70.

Granting inevitable limitations in the application of the method, these results indicate a high degree of latent predictability in behavior traits manifested in the first year of life. Furthermore, the results do not suggest that fundamental individual differences increase markedly with age. The differences may become more conspicuous without undergoing a true increase.

During the treatment of the data we posed to ourselves a more difficult question, namely: *Are persisting traits of behavior individuality observable in the first sixteen weeks of life?* For three of the subjects, Boy D, Girl A and Boy A, we had ample cinema records for testing such early predictability. When all the estimates were reviewed, it was found that the following traits were definitely noted and correctly appraised (in terms of prediction) prior to sixteen weeks, in all three children: Energy output, Motor demeanor, Self-dependence, Emotional expressiveness, Readiness of smiling. For two of the children the following traits also were recognized prior to sixteen weeks. Social responsiveness, Communicativeness, Adaptivity

Every infant seems to have what may be called a motor habitude or characteristicness which expresses itself in postural demeanor and modes of movement. This characteristicness is difficult of description because it is the compound result of numerous factors, including skeletal frame, disposition of musculature, speed, synergy, smoothness and precision of action. Some of these factors yield to quantitative study.

One of the most accessible of these is laterality, and even this presented wide variation among the five individuals. By laterality we mean right or left predilection or predominance in motor adjustment. One of our infants (Girl A) showed unmistakable left-handedness as early as twenty-eight weeks. She has remained definitely left-handed for five years (see Fig. 3). She always will be essentially left-handed. Boy A showed a less marked tendency to left-handedness. Boy D has been emphatically right-handed.

Foot dominance was determined by a careful study of the preferred foot used in prone progression Boy D showed right foot dominance at thirty-six weeks; Boy A, left foot dominance at forty weeks, Girl B and Boy B, left foot dominance at forty-eight weeks. This dominance is a well-established trait, but we do not know how late in life it persists

In general bodily control and also in manual dexterity, the four children for whom quantitative data were secured readily fell into the following rank order: 1, Boy D; 2, Boy A; 3, Girl B; and 4, Boy B. Several hundred feet of cinema records were available for measuring the *prehension time* of these children in controlled normative situations. The interval consumed between the zero moment of reaching to the moment of grasp of the test object was computed by counting cinema frames. Each frame has a time value of .05 second. The *prehension time* (that is, the reach-grasp time) increased with the rank order as follows: Boy D (rank order one), 40 seconds; Boy A (rank order two), 47 seconds; Girl B (rank order three), 50 seconds; and Boy B (rank order four), 60 seconds.

In these time values we apparently have a rather basic trait of motor individuality, for this rank order held up with consistency when the patterns of prone progression were measured in detail. For these measurements over a thousand feet of film depicting creeping behavior were available.

Creeping speed, like prehension time, was measured by counting frames, in this instance the number of frames which recorded a forward movement of a hand or of a leg. A *creep advance* represents a single cycle of progression accomplished by a single forward placement of each of the four members. The total time required for one creep advance was determined for each of the subjects in turn The time values ranged from .7 to 1.6 seconds for such a single creep advance. Once more the resulting rank order was identical with that just given in the preceding paragraph (see Table I).

Normally the ontogenesis of prone progression follows a sequence of 14 dis-

TABLE I

Motor Traits	Boy D	Boy A	Girl B	Boy B	Girl A
General control, rank order	1	2	3	4	
Manual dexterity, rank order	1	2	3	4	
Prehension time, rank order	1	2	3	4	
Actual time	40 sec	47 sec	50 sec.	.60 sec	
Progression.					
Creeping speed, rank order	1	2	3	4	
A creep advance (Stage 11)	70 sec	85 sec.	1.10 sec	1 60 sec.	
Near step advance (Stage 12)	.85 sec	85 sec.	1.05 sec	2 00 sec	
One step advance (Stage 13)	.90 sec	1.00 sec	1.60 sec.	2 15 sec.	
Alternation pause, rank order	1	2	3	4	
Simple creep (Stage 11)	.65 sec	.95 sec	1 65 sec	1 65 sec	
Near step (Stage 12)	.035 sec	04 sec.	045 sec.	.26 sec	
One step (Stage 13)	05 sec	.05 sec.	.20 sec.	.38 sec.	
Age of attaining near step stage	36 wks	40 wks.	48 wks.	48 wks.	
Summated rank of ages of attaining each of 14 stages	38	43	70	78	
Laterality					
Age of foot dominance	36 wks	40 wks.	48 wks.	48 wks	
Dominant foot	Right	Left	Left	Left	
Dominant hand	Right++	L–R (28 wks.)	Right	Right	Left++ (28 wks.)

tinguishable stages. Several of these stages were comparatively studied in our infant subjects. The simple creep advance just described represents the eleventh stage of progression and is generally characteristic of the age of 40 weeks. The *near-step advance* (stage 12, characteristic of 42 weeks) represents the next stage of progression. At this stage, the infant straightens the foot at the ankle and brings it toward a plantigrade posture without actually stepping. This new maneuver consumes additional time. The time values for this behavior pattern were determined, and again the children remained in the rank order already ascribed.

At the *one-step advance* stage (stage 13 : 45 weeks), the infant definitely plants the sole of his foot on the locomotion surface. This additional complication requires still more time. In this instance the time values ranged from .9 to 2.15 seconds for the four children, but again the characteristic motor rank order remained undisturbed.

Prone progression is accomplished by alternation of forward thrusts of one arm and the contralateral leg. Between these diagonal thrusts there is a palpable pause which can scarcely be observed by the naked eye, but which can be ascertained and measured by cinemanalysis. This pause diminishes in time for the three types or stages of creeping just mentioned. It however remains at any given stage highly characteristic of the individual, and accordingly the rank order for the alternation pauses remains constant for the four children.

Another individual difference asserted itself with respect to the age at which the various stages of prone locomotion were attained. For example, the ages when the near-step stage was attained were as follows: Boy D, 36 weeks; Boy A, 40 weeks; Girl B, 48 weeks; Boy B, 48 weeks. When the nascent ages for the entire sequence of fourteen stages in the ontogenesis of progression are expressed in terms of summated rank for each of the four children we get a significant series of values: Boy D, 38; Boy A, 43; Girl B, 70; Boy B, 78. Again the rank order remains true to the characteristic order established by the measurement of specific motor traits.

The accompanying table summarizes these measurements based upon frame by frame cinemanalysis.

In general the most accurate predictions were made for Boy D and for Boy B. These two boys presented contrastive behavior traits, which we may now summarize, if the reader will kindly understand that we do not suggest that one set of traits is necessarily superior to the other set. Each boy, like each of us, is in his psychological make-up a mixture of assets and some liabilities.

As early as the ages of 8 and 12 weeks the highly dynamic personality of Boy D made a strong impression even when observed only through the medium of the cinema. After a full year of recorded behavior had been subjected to such inspection the following adjectives were used to characterize his individuality: quick, active, happy, friendly, well-adjusted, vigorous, forceful, alert, inquisitive. Although he was definitely extrovertive he showed at the early age of 24 weeks a surprising discriminativeness in reading the facial expressions of his mother. By the age of 28 weeks he had developed a moderate temper technique for influencing domestic situations which did not altogether please him. He was able to shift quickly in his emotional response from smiling to crying and from crying to smiling to achieve a desired end. At the age of five years, likewise, his emotional reactions are labile and versatile. He is facile in changing his emotional responses. He is highly perceptive of emotional expressions in others and, correspondingly, highly adap-

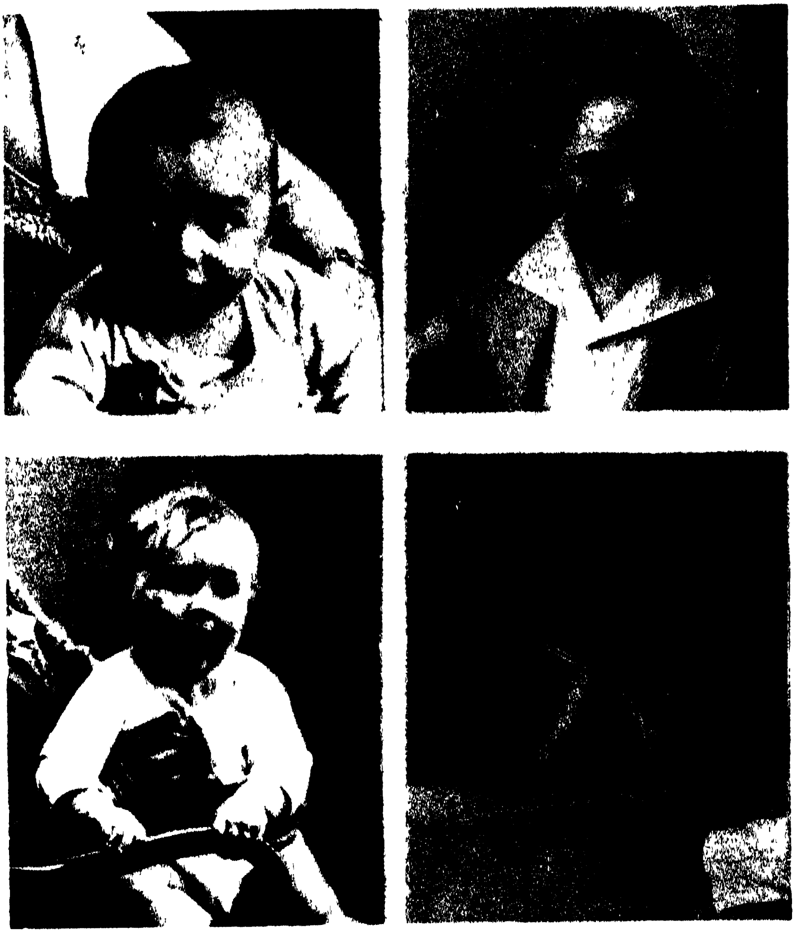

FIG 4 TWO OF THE SUBJECTS WHOSE INDIVIDUALITY WAS STUDIED IN INFANCY AND AT FIVE YEARS OF AGE.

tive in social situations With this emotional alertness he shows a relatively vigorous detachment from his mother as well as affection for her. He is not given to persisting moods. We do not get the impression that his emotional characteristics have been primarily determined by his life experiences. The underlying nature of his "emotivity" at 12 weeks, at 52 weeks and at 260 weeks seems rather constant. With altered outward configurations a certain characteristicness in emotional reactions is quite likely to persist into his later life.

Boy B presents a different constellation of characteristics. Although by no means emotionally shallow, he is by comparison less vivid, less expressive, more self-contained than Boy D. He is a sturdy, deliberate, moderately sociable, friendly child whose characteristics were evident at one year as well as at five years.

Boy B still shows motor ineptnesses and inhibitions comparable to those which he displayed in infancy. Boy D, on the other hand, has given consistent evidence of superior motor coordination from an early age in postural control, locomotion and manual dexterity. At twenty weeks he manipulated a string of wooden beads with precocious discriminativeness; at forty-four, he actuated a hinged rattle with a clever screwdriver movement of the wrists; at one year he pulled out an electric plug in an adaptive manner. At two years he repeatedly inserted and reinserted electric plugs, adjusted bridge lamps, latched and unlatched doors and operated an egg beater. The drive and deftness of his ceaseless manipulation strongly suggest in this instance mechanical insight and aptitude.

We have devoted a paragraph to motor traits because they best lend themselves to objective statement. If other traits of individuality become equally amenable to measurement and appraisal, applied psychology will be increasingly concerned with the detection of individual differences in the first year of life. With the aid of the cinema our exploratory study has demonstrated a significant degree of internal consistency in the behavior features of the same children at one and at five years of age. This consistency seems to rest upon biological characteristicness; a characteristicness which as yet can not be quantitatively formulated in a satisfactory manner but which is incontrovertible.

Our findings must not be over-generalized, but they strongly indicate that certain fundamental traits of individuality, whatever their origin, exist early, persist late and assert themselves under varying environmental conditions. This does not mean that physical and cultural environments have no influence upon the growing organism. It is suggested, however, that this influence may be properly envisaged as operating upon and subject to basic constitutional characters. The extrinsic environment impresses circumstantial and topical configurations, but a certain *naturel* is given, and it is for this reason that we discover such early evidences of individuality in the human infant.

Since we must tread warily in this field of discourse, we shall conclude with a vague but pregnant passage from Shakespeare:

> A man may prophesy with a near aim of the chance of things, as yet not come to life, which in their seeds and weak beginnings lie intreasured. Such things become the hatch and brood of time.

WHAT DO WE SPEND OUR MONEY FOR?

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IT is obviously desirable to know what wants or desires are gratified by our uses of our time, energy and material resources. It would also be desirable to know what wants are gratified by our use of our abilities, interests, ideals and other mental resources; but since we do not use these up by using them, the problem is a different one. I have reported data concerning expenditures of time in the SCIENTIFIC MONTHLY of May, 1937. The present report concerns what we get for our money.

According to Lynd,[1] the people of the United States spent in 1929 8,000 million dollars for clothing, 1,500 million for laundry, cleaning and dyeing, 750 million for death and burial and 3,500 million for life insurance. We inquire how much of the 8,000 million spent for clothing was spent to gratify the desires for protection against cold, wet, animals, diseases, pain, for the reproduction of the human species, for pleasures of vision, for a happy sex life, whether by sensuality, romance, philandering, courtship or otherwise, for affection (*i.e.*, to obtain it), for the approval of others, for self-approval, *i.e.*, the sense of personal worth, for dominance over others, for the welfare of others and for any other desire which in fact led any person to buy clothing for himself or anybody else We ask similar questions concerning the nation's laundry bill, funeral expenses and insurance payments.

It may be admitted at once that nobody can answer such questions accurately save by an enormous amount of careful and impartial observation of a representative sampling of persons in respect of what they buy, what they do with it and what desires seem to be operating in the case of their purchasing and use. On the other hand, economists, business men, sociologists, psychologists and intelligent people in general are observing pertinent behavior constantly, and have a fund of facts which are far above zero knowledge and, we may hope, fairly free from constant errors of prejudice. It may be very useful to collect and organize samples from this fund.

This we have done, using as our retrospective observers eight psychologists (six men and two women), five women (including experts in nutrition, home economics and the family), three economists and a small miscellaneous group of intelligent persons. The opinions of this last group will be used only in part or occasionally as a check.

After some experimentation the list of wants shown as the headings in Table 1 was selected as representing fairly well the fundamental cravings and satisfactions of mankind, being fairly comprehensible to others than psychologists and being brief enough to make the organization and record of opinions fairly easy. Table 1 presents the estimates of the eight psychologists (there are ten records because two of the men made independent judgments after an interval of some months) concerning the allotment of 80 units of a hundred million dollars each spent for clothing. Table 1 also presents the estimates made by the five women, the three economists and two from the miscellaneous group. Table 1 is a fair sample of our data. It shows a wide variation in the amount allotted to any one want, part of which variation

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[1] "Social Trends," Vol. II, p. 889.

TABLE 1

TWENTY ALLOTMENTS OF THE 80 UNITS (OF 100 MILLION DOLLARS EACH) SPENT FOR CLOTHING, BY EIGHT PSYCHOLOGISTS (p), FIVE WOMEN INCLUDING EXPERTS IN HOME ECONOMICS (w), THREE ECONOMISTS (e), AND TWO OTHERS (m)

	A. Hunger	B. Protection against cold, heat, wet	C Exercise	D Sleep, rest	E Sex relief	F Reproduce species	G Protection against animals and diseases	H Protection against bad people	I Reduce or avoid pain	J Pleasures of taste and smell	K. Pleasures of sight and sound	L Sex entertainment	M Security	N Affection (to get it)	O. Companionship	P Approval of others	Q Approval of one's self	R Mastery over others	S The welfare of others	T Mental activity	U Curiosity and exploration	V Social entertainment	W Physical entertainment	X Comfort not in A to W
p1a		30					8		2			5				15	10	10						
p1b		25			2	7	5					2		2		25	3	3						6
p2a		47					2		1				5			10	5	5						5
p2b		40					4		1		3	3	4	1	1	15	5	2						
p3		20					10		2		10	20	6		4	5	5				1	2	1	
p4		30	5	1					2			7		6 5	4	8	10	5	4		2			
p5		34					10		1		6	7				12	6	1				2	1	
p6	1	20					11	1	3		10	5	10	5	1	1	1	1	1			5	1	2
p7		36					5	3	1		10	5		1		10	2	5						2
p8		20	1		4		2				3	15	4	5	5			10	3	1	1	5		1
w1		40					3					10				10	7					10		
w2		35	1	1							14	10		3		10	5							1
w3		15			8							8		5		8	5	5	8			15		3
w4		35	2	2			3				1	1	1	2	1	5	2	4	8			10	2	1
w5		40					1	1			5	10				10	6		5				2	
e1		14					2	3			10	10			5	15	5	10						
e2		40	1 6	1 6			16				8	1 6		1 6	8	16	2 4	8				4		
e3		20					2				10					40	8							
m1		64					2 4	2 4				1 6				4	3 2							2 4
m2		6					6				10	15		8		5	20	5						5

is doubtless due to errors of inaccurate observation, prejudice and inadvertence, but much of which is due to important differences in point of view and observations.[2] This variation is consistent with substantial agreements—of the psychologists *inter se*, and between them and the average of the other ten (the latter correlation being .85).

The only indubitable errors are the following: Psychologist 4 and Women 2 and 3 assign nothing of the 8,000 millions for clothing to protection against animals and diseases, probably by sheer inadvertence, though they might argue that the clothes people wear do not demonstrably keep them from harm or increase their health. Misc. 2 assigns only 6 of the 80 units spent for clothing to the desire to avoid cold, heat and wet. This ratio of 1 in 13 could perhaps be true of city dwellers who live largely indoors and spend $200 a year or more on clothing, but is surely far wrong for the many whose clothes cost less than $40 a year, and too low for the average. Psychologists 1 and 4, Women 1 and 3 and Misc. 1 assign 0 to the pleasures of sight, whereas 3p, 6p, 7p, 2w, 1e, 3e and

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[2] There is evidence in Table 1 and the thirty-two other similar tables (for food, rent, home-furnishings, fuel and light, etc.) that individuals impute to the general population desires unduly like their own and are somewhat blind to the existence and operation of desires which they lack and to behavior which is alien to them. Consequently, the estimates as a whole may err in the direction of a too intellectualistic, cultured and refined interpretation of the nation's expenditures.

2m assign 10 units or one eighth of the total to this. the former are probably wrong, neglecting the fact that a person may look at himself in mirrors and may buy good-looking clothes to gratify what he thinks of as the desires of others for pleasures of sight, rather than as his own desire for their welfare. The latter are probably wrong in imputing to the desire to have pleasure in looking at oneself force which belongs rather to the desire for approval, dominance and unspecified comfort, and in exaggerating the craving to give others beautiful objects to look at They were probably too much influenced by the thought-sequence "clothes—to look well—pleasures of sight." These twelve errors more or less cancel each other, as often happens in our records. Apart from them there are only four indubitable errors in the 480 estimates.

I have searched all the allotments for laundry, cleaning and dyeing, death and burial and life insurance for errors Of the $150,000,000 spent for laundry, cleaning and dyeing, four persons allot nothing to the desire for protection against disease; seven allot nothing to the desire for pleasant smells; four allot nothing to the desire for the approval of others, four allot nothing to the desire for self-approval. These are all probably due to forgetfulness or neglect of certain facts of life. It is natural for refined persons who work in offices to forget about vermin, barnyards, babies and sweat. It is natural for scholarly males to neglect the tribute which clean clothes bring. These nineteen errors more or less cancel one another. In the case of the expenditures of 750 million for death and burial we may criticize one person's allotment of 350 million to social entertainment, and that of another who allots 400 million to the desire for affection. The amounts seem surely excessive. In the case of life insurance an assignment of 500 million to the desire for company is probably a clerical error, the number being probably intended for the next box above, which is "Affection." The assignment of 0 to "Welfare of others" by two persons is wrong These persons seemed to have endowment insurance and enforced insurance exclusively in mind and to forget that with the former the person is paying for possible benefits to others than himself. As in the case of clothing, errors are few and often compensating so that the average of ten or twenty opinions is fairly dependable.

Table 2 presents the average opinion of the two juries (psychologists and others) concerning what we spend our money for when we buy food, clothing, rent, life insurance, laundry, cleaning and dyeing, funerals and burial. The reader will note that purchases of *food* are judged to contribute appreciably to every one of the twenty-four satisfactions except protection against bad people, that purchases of *clothing* are judged to contribute appreciably to every one except the pleasures of taste and smell, and that *rent* is judged to contribute to all without exception. The reader will perhaps think that some of these allotments should be reduced to zero, because he himself gets no such gratifications from his payments, but he is probably wrong.

The table shows that the two juries agree rather closely.[3] The psychologists tend to break away oftener and further from the conventional overemphasis on food for hunger, clothing for warmth, rent for shelter and insurance for security. Each entry in Table 2 has a certain interest, but we have more important facts to consider.

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[3] The closeness of agreement between the two juries is measured by the following correlation coefficients: food, .85; rent, .89; clothing, .85; laundry, etc., .79; life insurance, .71; death and burial, .84.

TABLE 2

AVERAGE ALLOTMENT (I) BY PSYCHOLOGISTS AND (II) BY OTHERS OF 1,700 UNITS SPENT FOR FOOD, 800 UNITS SPENT FOR CLOTHING, 800 UNITS SPENT FOR RENT, 400 UNITS SPENT FOR HOME FURNISHINGS, 480 UNITS SPENT FOR FUEL AND LIGHT, 350 UNITS SPENT FOR LIFE-INSURANCE, 150 UNITS SPENT FOR LAUNDRY, CLEANING AND DYEING AND 75 UNITS SPENT FOR DEATH AND BURIAL (THE UNIT BEING 10 MILLION DOLLARS) AMOUNTS ARE TO THE NEAREST UNIT, LESS THAN 5 MILLION DOLLARS BEING ENTERED AS 0

	Hunger	B Protection against cold, heat, wet	C Exercise	D Sleep, rest	E Sex relief	F Reproduce species	G Protection against animals and diseases	H Protection against bad people	I Reduce or avoid pain	Pleasures of taste and smell	K Pleasures of sight and sound	L Sex entertainment	M Security	N Affection (to get it)	O Companionship	P Approval of others	Approval of one's self	Mastery over others	The welfare of others	T Mental activity	U Curiosity and exploration	Social entertainment	Physical entertainment	Comfort not in A to W
Food																								
I	876	27	0	3	3	21	50	0	26	275	62	45	8	15	48	71	5			1	4	74	3	46
II . . .	931	20	12	2	5	7	48	0	5	202	15	64	2	25	37	53	10			1	10	170	3	20
Clothing																								
I	1	302	2	1	6	7		4	13	0	42	69	29	21	14	101	47	42	8	1	4	14	3	16
II	0	309	5	5	13	1		0	6	0	58	67	1	20	7	123	64	25	21	0	0	39	4	12
Rent																								
I . .	15	235	4	94	22	20	37	36	3	4	21	21	80	16	18	48	28	13	28	3	1	31	3	17
II	8	250	1	66	9	17	36	30	2	3	40	25	35	13	10	78	44	6	31	2	2	48	6	39
Life Insurance:																								
I		0	0	1	0	17	3	0	3	0	0	2	73	23	5	29	48	2	143	0	1	0	0	0
II		0	0	0	0	10	8	6	3	0	0	2	166	12	0	3	8	1	124	0	0	0	0	7
Laundry																								
I . . .		6	1	5	1	2	26	0	1	9	14	13	1	0	1	25	18	3		0	0	4	0	15
II		3	1	0	0	1	12	0	3	9	21	5	0	4	1	32	20	1		0	0	8	3	11
Death and burial																								
I	0	0	0	0	0	0	6	0	1	0	0	0	4	5	0	28	13	1		0	0	3	0	10
II	0	0	0	0	0	0	5	1	0	2	0	0	9	4	0	28	6	0		0	0	4	0	8

We may extend Table 2 by similar tables for the 33 items listed below, which represent Lynd's list with additions computed or estimated by Dr. Ella Woodyard (chiefly from various tables in *Business Week,* April 27 to September 7, 1932), and with certain items grouped.

ESTIMATED EXPENDITURES IN 1929 (IN UNITS OF 100 MILLION DOLLARS)[4]

1. Food	170
2. Clothing	80
3. Rent	80
4. Home furnishings	40
5. Fuel and light	48
6. Life insurance	35
7. Religion	9
8. Automobile (purchase and use)	65
9. Travel	20
10. Motion pictures, theaters, concerts, etc.	20
11. Clubs, lodges, etc	4
12. Indoor and outdoor games, sports	9
13. Newspapers	4
14. Radio and musical instruments	6
15. Jewelry and silverware	6
16. Flowers from florists	2
17. Cosmetics, beauty parlors	7
18. Physicians	10
19. Dentists	4
20. Hospitals, sanitariums	11
21. Medicine (patent and prescription and other medical costs)	10
22. Laundry, cleaning, dyeing	15
23. Tobacco	16
24. Confectionery and chewing gum	7

25. Drinks and narcotics (not tobacco)	27
26. Correspondence and communication	10
27. Leather goods and luggage	3
28. Investments	95
29. Education	16½
30. Welfare	6
31. Death and burial	7½
32. Legal services, fine, penalties, etc., including divorces	3½
33. Taxes, local, state and federal	64

If the 33 amounts assigned to each of the 24 wants are summed, we have estimates, by our twenty observers, of the total amounts paid to avoid hunger, cold, heat and wet, get exercise, sleep and rest, etc These amounts and the percentages which they are of the total expenditures are presented in Table 3, which may be called a budget in terms of wants or satisfactions. The allotments by the two juries agree rather closely, the correlation (omitting X, miscellaneous satisfaction or comfort), being .92[5]

Table 3 is much more dependable than any of the thirty-three separate tables whence it is derived. Imperfections in the allotments of one sort of expenditures by the two juries will be largely counterbalanced by contrary imperfections in the allotments of other sorts.

TABL 3

THE TOTALS OF THE 33 ITEMS OF EXPENDITURES AFTER ALLOTMENT (I) BY THE PSYCHOLOGISTS AND (II) BY THE GROUP OF ECONOMISTS, EXPERTS IN HOME ECONOMICS, ETC.

			II	
	In units of $10,000,000	In percents of the total	In units of $10,000,000	In percents of the total
A Hunger	1,018	11.2	1026	11 3
B Protection against cold, heat, wet	925	10 2	889	9 8
C Exercise	39	4	63	.7
D Sleep, rest	239	2 6	184	2 0
E Sex relief ..	77	8	81	9
F Reproduce species ..	172	1 9	73	.8
G Protection against animals and diseases	404	4 4	377	4 1
H Protection against bad people	227	2 5	140	1.5
I Reduce or avoid pain	322	3 5	209	2.3
J Pleasures of taste and smell	414	4 6	434	4 8
K Pleasures of sight and sound ..	359	3 9	471	5 2
L Sex entertainment .	356	3.9	374	4 1
M Security	959	10 5	1015	11.2
N Affection (to get it)	163	1 8	169	1 9
O Companionship ..	210	2 3	211	2 3
P Approval of others	657	7 2	653	7.2
Q Approval of one's self	367	4 0	347	3 8
R Mastery over others.	276	3 0	164	1 8
S The welfare of others	656	7 2	786	8 6
T Mental activity .	175	1 9	210	2 3
U Curiosity and exploration	168	1 8	211	2 3
V. Social entertainment	380	4.2	613	6 7
W Physical entertainment	104	1 1	115	1 3
X Comfort not in A to W	411	4 5	273	3.0

Table 3 states that we spend about one ninth of our money to ward off hunger, about one tenth to keep warm (or cool) and dry, that only a few eccentrics pay money for exercise, our payments for games and sports being for entertainment rather than exercise, that we spend much time but little money for rest, that the mental features of sex life cost us about five times as much as the physical, that the reproduction of the species comes chiefly as a by-product, that we pay twice as much for protection against diseases as for protection against bad men (or did in 1929), that sheer sensory pleasures and the avoidance of pain (exclusive of hunger, cold, heat, wet and fatigue) account for only about one eighth of our budget. Some Freudian psychiatrists say that what human beings want above all else is love and

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[4] The accuracy of the absolute numbers in these expenditures is of no importance to our argument. The accuracy of their relationships one to another is of importance, but not so much as would be thought offhand. The probability is that any reasonable estimate of the national budget of expenditures would produce about the same distribution among wants as this one does, with one exception The year 1929 was more of a luxury year than the average, and to that extent our conclusions are somewhat biased against the necessities of food and lodging.

[5] It would probably be higher if each person's X could be distributed among A to W.

security, but in Table 3 security averages under 11 per cent. and affection under 2 per cent. We pay more to get companionship than to get affection. Approval of others and of one's own self (conscience, self-respect, pride, etc.) rival hunger and security. A cynic may say that the percentages for Item S (the welfare of others) in Table 3 show modern civilized man to be only one twelfth altruist and that the percentages for item T show him to be only 2 per cent. intellectual. This is harsh, neglecting the *time* that persons (mothers especially) spend for the welfare of others, and the fact that a fine intellectual life can now be lived at almost no pecuniary expense, and also neglecting certain facts of Table 3 itself. But Table 3 does fall far below the ideals set by moralists For entertainment (L, V and W) we spent more than for mental ability and the welfare of others combined.

Table 4 shows the allotments to various groups of wants, compiled from Table 3. Less than a third of the expenditures are allotted to keeping the population alive, well and able to reproduce itself. The pleasures of the senses take a tenth; the pleasures of the intellect less than half that. The selfish satisfactions which depend rather directly upon our fellow men take over a fifth This becomes over a third if the satisfactions of the love-life and benevolence are included. The desire for security takes a tenth, an eighth if security from bad men is also included. By Table 4, Homo (of U S. A. 1929) seems much more sociable than sapiens. He seems to be mainly a hedonist, but most of the pleasure he seeks is not of the senses.

TABLE 4

THE TOTALS FOR GROUPS OF WANTS, COMPUTED FROM TABLE 3 AND EXPRESSED AS PERCENTAGES

	I By psych	II By others
Subsistence, perpetuation and some increase of the stock (A, B, C, D, E, F and G)	31.6	29.6
Pleasures of the senses, bodily activity, intellect and love life (I, J, K, T, U, W, L and ½ X)	23.3	23.8
Security (H and M)	13.0	12.7
Social satisfactions (N, O, V, P, Q, R and ½ X)	24.8	25.2
Benevolence (S)	7.2	8.6
Total	100.0	99.9
Subsistence, etc. (A, B, C, D, E, F and G)	31.6	29.6
Reduced pain (I)	3.5	2.3
Pleasures of the senses and bodily activity (J, K and W)	9.6	11.2
Love life (L)	3.9	4.1
Pleasures of the intellect (T and U)	4.0	4.6
Security (H and M)	13.0	12.7
Company, affection and social entertainment (N, O and V)	8.4	10.9
Approval, social and self (P and Q)	11.3	11.0
Mastery or dominance (R)	3.0	1.8
Benevolence (S)	7.2	8.6
Comfort not included in the above (X)	4.5	3.0
Total	100.0	99.8

Tables 3 and 4 are subject to correction and improvement, but they give, I think, a better picture of the ultimate satisfactions for which those with purchasing power use it than has hitherto been available.

There are two feasible ways to correct and improve the picture. The first is to follow the method used here, but with other and possibly better measurements of expenditures, with other and better lists of wants, and with larger juries of psychologists, economists, business men and specialists, familiar with the behavior of consumers, white and black, in city and country, north and south, rich and poor. Our twenty judges may have a constant error in the direction of exaggerating such satisfactions as they themselves and their friends and acquaintances feel and pay for, and so underweighting the influence of the vulgar rich, the wretchedly poor, the very dull, the mean and cruel, the dwellers on farms, etc. It would be especially useful to have allotments made by wealthy persons and by social workers who are familiar with what the poor buy and why they buy it, and to estimate from these the magnitude of this possible error.

"What we spend our money for" may be translated into "What we spend our working time for," and then combined with the facts reported in the earlier article about our uses of leisure. The combination will give some idea of the gratifications for which all our days are spent.

Time not spent at work or sleep was found to be spent largely for entertainment (including the pleasures of the senses and of the love life), companionship, affection and approval. Much of working time also is spent for these. I estimate that about a third of waking hours are spent for entertainment in this broad sense, about a tenth for companionship and affection and about a tenth for the approval of self and others Generous estimates of the use of leisure time for intellectual activity other than for entertainment and for the welfare of others would be around one twentieth in both cases This would give for all working hours about 4 per cent for intellectual wants and about 8 per cent for the welfare of others.[6] Most people devote few or none of their leisure hours to the security which is a main purpose of their work. The total is about 7 per cent. The needs of subsistence, perpetuation and some increase of the human race in this country account for about a fourth of our waking hours.

I conjecture therefore that the 16 hours of the waking day of adults in the United States are spent roughly as follows·

25	per	cent.	for subsistence and perpetuation.
2	"	"	to avoid or reduce sensory pain
7	"	"	for security.
8	"	"	" the welfare of others.
30	"	"	" entertainment.
10	"	"	" companionship and affection.
10	"	"	" approval.
4	"	"	" intellectual activity.
2	"	"	" dominance over others.
2	"	"	" other wants

These allotments are easy to criticize I myself could put down reasons why this or that one is probably wrong. But they are at least honest, impartial conjectures based on facts.

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[6] This estimate is specially insecure because the budgets of time include none for mothers. I have had to guess what allotment to make for them.

AN ADVENTURE IN ETYMOLOGY[1]

II. MEANING IN BIRD–NAMES

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THE giving of names to animals is as natural as attaching them to hills and rivers. It was one of the first products, no doubt, of the practice of human speech and remains a characteristic of every dialect into which speech is now diversified; moreover, the nomenclature of natural history has grown up everywhere in the world, ancient or recent, in strikingly uniform lines of development. Names, in fact, are mere labels—aids to memory and means of arrangement and record. As did the most primitive people, so subsequent explorers and settlers in each new region seize on what at the moment seems the most striking feature in each animal or object they encounter; and their designations often stick forever, however erroneous they are later found to be.[1]

Most birds owe their names in everyday speech to one or another of four noticeable features: (1) color, (2) voice; (3) form, as a whole or in detail; (4) some striking peculiarity in method of life. Occasionally two characteristics are combined, as in "bluejay," which expresses both color and voice. Many of the present names of our American birds, especially those of generic breadth, are modernized forms of ancient English words of Scandinavian or French parentage or of so remote a foreign origin that their primitive significance can hardly be guessed; nevertheless, a queerly disguised and even amusing parentage will often reward search. The term "bird" itself, for example, is sister to "bride," and both contain the implication of a brood.

Readers will now perceive, by recalling the four classes of name-source just mentioned, that birds are commonly known by names so matter-of-fact and obvious as to need little or no explanation: the red, black, and blue birds; those that tell their own names, as killdeer, bobwhite, chickadee; those of familiar habits or flight, as woodpecker, hummingbird, etc. Also, it must be remembered that a long list of American species and subspecies recognized by scientific ornithologists, and recorded in international classification, have no "common" names at all. Thus space is left free to be devoted to that minority of our feathered friends of the forest, the meadow, the garden and the water-spaces. These bear labels the origin and interpretation of which may henceforth engage attention. I shall lead the inquiry in a general way, as a matter of convenience, along a line partly of popular interest in birds and partly of modern classification; therefore I make no apology for beginning with the birds of prey.

The names of few American raptorial birds require explanation. These hunters of the air fall into five groups: Eagles; Buteos (buzzards) and harriers; Falcons, long-winged, heroic hunters; Fishhawks; Kites. The broad word "hawk" is the old Saxon *hafoc,* a killer; the largest of the race are the eagles, and of these the grandest is the golden eagle, Bird of Jove.

Eagle is the Latin *aquila* transformed into English by aid of the French *aigle.* An Irishman with a fair brogue reproduces the word's birthstory when he cries the toast:

> Here's to the American Aigle,
> Whom none can invaigle,
> Nor put salt on his beautiful tail!

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[1] SCIENTIFIC MONTHLY, 44: 2, 157, February, 1937.

The original English name of this bird was the widely spread northern word *earn,* which has become useful as "erne" in dialect poetry and in cross-word puzzles. Our national emblem, the "bald" eagle, owes its misnomer to the cap of white feathers on the head of adults; it is, as Benjamin Franklin told Congress, when it was proposed to put it on the seal of the new United States, "a bird of a bad moral character"—a shameless bandit Far nobler is the species we call "golden" because of the golden gloss that suffuses the feathers of the neck when mature, and far better had the name "war-eagle" been popularized for it, and had its image been engraved on our seal instead of that of its less worthy cousin. Such a distinction would have been appropriate, too, because this bird was the war-eagle of the Indians—America's natives—and was held in almost divine respect This noble eagle is a resident of the whole northern hemisphere, and its history as a warrior is equally broad, for it has figured as a symbol of imperialistic pride and power from the rise of Babylon to the fall of Rome.

The Buteonine group contains what Europeans style buzzards, originally a medieval sportsman's expression for an inferior kind of hawk as used in the chase. Most of the short-winged hawks, so called in this country, are the "redtails," "broadwings" and their like, which are the "henhawks" of rural complaint, though most of them are almost innocent of attacks on game or poultry. Guilt in this respect belongs mainly to the small accipiters, such as the sharpshin (J. G) Cooper's hawk, the goshawk (*i.e.,* goosehawk) and in a minor degree to the marsh "harrier." These keen, swift hunters of living prey introduce the falcon type.

Falcons are the true birds of prey. They take their ancient name directly from the sickle-like (Lat. *falx,* a sickle) curvature of both beak and talons—instruments of grasping and tearing power closely like the teeth and claws of cats; and they do in the air exactly the service nature requires of tigers and wildcats on land—destruction of the weak in favor of the strong. The term "falcon" came into Britain when "the sport of kings" was brought in the trail of William the Conqueror. At first it belonged to the peregrine (our "duck-hawk") and strictly meant the female. Two other old sporting names frequently met with in books are merlin and kestrel; the former is represented by our pigeon-hawk, and the latter by our sparrow-hawk.

Falconry, or hawking, as the English prefer to style the sport, brought with it an extensive and special vocabulary, much of which is obsolete. The terms designating the trained birds themselves in their various ages or in the phases of their work seem to me worth recounting because some of them recur often in histories or novels Falconers spoke of a hawk lately from the nest as an eyess; when able to take game as a soar hawk; a mature wild hawk they called a haggard or blue hawk. A male falcon was called a tiercel or thirdling, from the belief that a bird produced from the third egg laid in a clutch would necessarily be a male.

Our *Fish-hawk* is the same as the bird known in the Old World as osprey, which name is a compound of two Latin words equal to "bone-breaker"; an older form used in the Bible (Lev. xi: 13) is ossifrage. As the fish-hawk (osprey) is rare in Bible lands, and does not break large bones, it is probable that the great alpine vulture, the lammergeir, was the bird really referred to by the sacred writer.

Kites were almost as numerous in and about London in the seventeenth century as are sparrows now, and were valued and protected by law and custom as scavengers; the name is plain *A. S. cyta.* The flying toy that we send up on a breezy day came to be called a kite (after its introduction to British youths about 1650) because in the air it resembled the sailing and poising of the graceful bird; it is in reference to this elegance on the wing that Chaucer and other early poets call a kite glede or "glider."

The American vultures have been unfortunate in this direction. The great Andean-Californian vulture was called *Condor* in a fairly close Spanish pronunciation of its native (*Cuntur*) name in Peru. Ignorant colonists in some southern colony inflicted the quaint compound *Turkey-Buzzard* on the larger of the two vultures in the United States, and called the lesser one *Carrion Crow* in misguided recollection of the carrion crow of Britain—a very different sort of fowl, destructive and disagreeable. This brings us to consider the gallinaceous tribe.

The popular names of game-birds are amazingly mixed, and carry much of history and romance. The *Pheasant,* so carefully preserved in Britain, is of a species native to the region northeast of the Black Sea (the ancient Colchis), and took its name from the river Phasis there, whence the first specimens were brought to Greece and thence spread over Europe long ago That pheasant lately acclimated in North America, the "ringneck," represents one of the many other species of Phasianidae in India and China. The domestic *Turkey* is a descendant of some variety of the bronze turkeys of southern Mexico sent alive to Spain in 1630 by the conquerors of that country When, later, this fowl spread in captivity to other parts of Europe, few knew whence it originally came—some said from India (the French still call it *coc d'Inde*), others said from Turkey. The last guess got the lead in England, so that when these fowls were brought to America by the first British colonists they came as "turkeys."

Grouse meant originally a gray bird (German, *graus*). Our grand, drumming, woodland species is distinguished by a "ruff" of erectile feathers upon its neck, which northern fur-traders used to call shoulder-knots or sometimes tippets. In New Brunswick, Maine and southward to Pennsylvania, this ruffed grouse is commonly known as "partridge"; further south it is a "pheasant" or "mountain pheasant." *Partridge* is the most abused word in American bird-talk—abused in form, spelling, pronunciation and significance; it is a distorted descendant of *perdix,* denoting in ancient Greece and Italy the small, gray, European game-bird introduced to us recently as "Hungarian partridge." That species is a cousin of the American quails, but our bird—the "bob-white"—is so different from the European type that properly it is not even a true quail, but must be classed with the Mexican colins; nevertheless, all over the north bob-white remains a *Quail,* and everywhere south of Maryland it is equally sure of being reported as a partridge—just the reverse of the way "partridge" and "pheasant" are separated.

Ptarmigan is the English spelling (since 1684) of the Gaelic word *tarmachan,* meaning white game, applied by Scottish shepherds to a northern, mountain-dwelling variety of the red grouse, a moor-fowl, which turned white in winter. When Scotsmen began to flow into Canada, and especially into the Northwest, they found there virtually the same white grouse and naturally called them ptarmigans.

Our *Prairie Chicken* has escaped the name partridge. It is the so-called "pinnated grouse." This fine bird was encountered by the first Puritan settlers in Massachusetts wherever open country favored its presence, and it was given the appropriate name *Heath-Hen,* which was retained by its survivors on Nantucket until its extinction in 1932.

The heath-hen in early days abounded on the plains of Long Island, New York, where, in 1791, a law was passed by the State legislature for its protection by a close season between April and October. A footnote in Brewer's edition of Wilson's "Ornithology" records a ludicrous incident that occurred during the discussion of this law, which was entitled "An act for the Preservation of the Heath Hen." The chairman of the Assembly—no sportsman, evidently—read this title as an Act for the preservation of the Heathen, which astonished the more northern Representatives, whose particular "heathen" were the still troublesome Indians of the Adirondacks. . . . The modern designation Prairie Chicken for this fine grouse is appropriate; and it is a vast pity that some pedantic classifier tacked upon it the awkward name "pinnated," as if the tufts of feathers beside its neck were wings!

Pigeon is an example of the strange changes that happen to an every-day appellation and its significance in its descent from the Latin (not to go further back) through medieval talk until established by dictionary makers into a modern form. Our English pronunciation differs little from the French or Spanish, but how *dg* or *ch* sounds, in all three languages, were derived from the Latin verb *pipio*, to pipe (in music) or to peep (as young chickens) is hard to understand In Italy this bird is now *piphione*, literally a young pigeon, a "peeper." Among us the word pigeon is virtually restricted to the domesticated varieties of the European bluerock and related pigeons of large size; but specifically it means in this country the native migratory or "passenger" pigeon, now extinct.

Dove is the original English name for the birds of the family Columbidae, and represents the very ancient Germanic form *dufa*, a diver; the essence of the Latin word *columba* is "diving." How this significance came to be attached to birds of a purely terrestrial nature seems beyond accounting for. The old-fashioned word "culver" for dove, regarded as a short and altered form of *columba*, has a place in archaic poetry, such as that of Chaucer, and is still heard in British provincial speech, as, also, are the Scottish words "cushie-do," or "cushat" for the ringdove, which refer, it is said, to its peculiar swift, straight flight. Our common eastern wood or "mourning" dove is frequently miscalled "turtle-dove," a term that belongs properly only to the small European species that the Latins spoke of as *turtur* in imitation of its soft cooing. The fact that our forefathers mispronounced the Latin word into "turtle," and so printed it in the English Bible, has made a comic confusion in the minds of devout but ignorant readers who do not know the difference in origin between the name of the bird and that of the reptile, the latter a rude corruption of "tortoise."

Owls and goatsuckers fall nicely together ornithologically and in our lexicon. Both are nocturnal in habit and are alike equipped with large eyes, soft, loosely knit feathers, big mouths and a strong desire to fill them. Few persons need be told, I believe, that *Owl* is simply a Cockney shortening of "howl"; an old owl is a howler, a young one a howlet. There is a story that a Londoner, scared in Canadian woods by an unearthly noise, was told: "It is only an owl." He responded: "I know it's a 'owl, but wo't in 'eaven's name is that 'owlin?" Thus a stranger had been introduced to the great, horned (not great-horned) terror of our forests, otherwise the cat-owl. Its body is great, but its "horns" are relatively small, and its upstanding crown-feathers should be called tufts, not horns or ears, as they are in smaller related species of this widely varied family.

The "hoot" owl of books is the barred species, locally rain-owl; the short-eared is the marsh or prairie owl of farmers; the saw-whet takes its quaint name from its chant, which reminds one of the filing of a saw, while its variety has become a sparrow-owl in the west; our barn-owl is identical with the British one, but has different habits and is rarely seen by those not looking for owls. "Screech-owl" is an ancient but very indefinite designation. Certainly the term ought not to be used in this country as it constantly is for our little red and gray crooner, because the gentle, wavering serenade with which he lulls us into sleep is the very antithesis of a "screech." Quebec people describe this bird of the moonlight as *le hibou macule,* and "mottled" would be a proper name for this small species, which is almost a replica of the little Grecian owl (*Athene noctua*), the special cognizance of the wise and stately goddess of the Athenians in their prime—Pallas Athene.

Goatsuckers, of the classically styled family Caprimulgidae, have rested for ages under a false and foolish label. Greek shepherds on Thessalian hills accused these birds, 3,000 or more years ago, of milking their goats in the night. I wish to drop this silly and libellous name from American currency and to put in its place *Nightjar,* borrowed from an English species, whose song is likened to the noise of an old-fashioned spinning-wheel. Our representatives of this family are the various whippoorwills and their cousins, the nighthawks, which latter have received that name among us because they resemble small falcons when they swoop and dodge in the twilight as they pursue their insect prey through the air overhead. At such times they utter a whirring, booming sound, which has given them in the southern states the nicknames "bullbat" and "piramadig."

Swifts are a cosmopolitan family renowned for marvelous evolutions in flight. We have a few species in the United States, the most conspicuous of which is the occupant of our chimney-stacks, commonly but wrongly called "chimney-swallow." In Europe swifts used to be known as martlets; and this word is employed in British heraldry to denote a footless bird—a figure borne on the escutcheons of certain old families. The notion arose from the tiny form of the swift's feet; but why they were also classed among "devil birds" is a mystery.

Hummingbirds took that name, of course, from the sound made by their rapidly moving wings. The first recorded notice of our eastern one, the ruby-throated hummer, occurs in a christening letter from John Winthrop, Colonial Governor of Connecticut, dated October 26, 1670, in which he mentions sending to a friend in England "the curiously contrived nest of a humming bird," so called, he explains, "from the humming noise it maketh while it flies " The Carib Indians told Columbus these birds were "colibri," and that name still exists in some of the West Indian islands. Imaginative Portuguese in Brazil have invented, or borrowed from the native Arawaks, such fanciful pet-names as flower-peckers, flower-kissers, myrtle-suckers; and the Peruvians and Mexicans have styled them rays of the sun, tresses of the daystar, and the like, and declare that they subsist on dew.

Woodpecker, as a name, is self-evident. In the southern states the absurd rendering "peckerwood" is heard, and there, especially, the giant of the family is a "logcock." Carpintero is the good Spanish name for all these birds in California and southward "Sapsucker" is often carelessly applied to any small woodpecker, but rightfully belongs only to the yellow-bellied, brush-tongued species of the American genus Sphyrapicus, which in spring pierce the outer bark of trees to get at the bast, soaked with sweet sap. Who first coined the nickname "flicker" for the ubiquitous golden-winged woodpecker is unknown, but it fits fairly well the repeated shout of this fine species as it flies from place to place, and has generally replaced a large number of insignificant local names, such as pigeon-woodpecker, highhole and yellow-hammer. The last mentioned would appear at first glance to be simply "yellow hammerer,'' but really it it a misplaced borrowing of the name given in England to any of several small birds more or less yellow in plumage, combined with the ancient Iclandic word *hamr* for skin —in other words a ''yellowbird.''

Cuckoo, now the application of a worldwide and surprisingly varied family of birds, simply repeats the spring-call of the European parasitic species, which thus conferred both name and reputation on its tribe. The two related American species make a stammering attempt at the British pronunciation but fail, nor are they parasitic. The *Roadrunner* or chaparral-cock of the Southwest belongs in this family, as also the *ani* (ah-nee) or mangrove-cuckoo of the Caribbean region. In the southern states our cuckoos are usually spoken of as ''rain-birds.'' Why? When our remote forebears were talking and writing ''Sanscrit,'' in northern India, among the nature-spirits in their religious scheme the Indian cuckoo was a mixture of symbol and practical ruler of the clouds and rainfall. The people did not distinguish very well between the symbolic or spiritual image and the actual bird—imagined their living cuckoo to be an inspired prophet in the all-important matter of rain. This reputation has descended to and been fastened upon all the cuckoos in the world, making them ''rain-crows'' everywhere.

Kingfisher. This seems an obvious label to any one who knows our belted representative of this extensive family, and was perhaps suggested by the bold way in which he controls what he has preempted as his part of a stream or lake-shore. He has inherited from his European relative the name Alcyon, which is frequently used as a synonym by writers of essays and poems here, thus connecting our bird, quite improperly, with the romantic traditions and fables of ''halcyon'' classic days, and with medieval tales and practices. These reminiscences, in which Old World fact and fable are curiously interwoven, I have retold and considered at some length in my ''Birds in Legend, Fable and Folklore'' (New York, 1923).

Lark is a word so old and altered that no one knows its original sense. It is traceable to the Anglo-Saxon *lawerce,* the skylark, and is retained in Scottish speech as ''laverock,'' a word constantly occurring in the verses of Burns and earlier poets. In the sixteenth century the spelling ''lerck'' prevailed, but the pronunciation then doubtless rimed with park. We have no true larks (Alauda) in the United States, except the widely distributed shore or ''horned'' lark, the latter name referring to the black, slender, erectile feathers on the side of the head. The so-called titlark and skylark of the western plains resemble true larks in form and singing, but are classified as pipits. The familiar ''meadowlark'' of this country is an associate of the orioles and marsh-blackbirds (Icteridae).

Flycatcher in American ornithology denotes a small bird whose food consists of insects caught on the wing, except that fed to nestlings All our species belong to the wholly American family Tyrannidae, long ago styled tyrant-flycatchers, with special reference to the bold, pugnacious behavior of the *Kingbird.* He royally defends his nesting territory against every intruder, and occasionally steps beyond kingly courtesy to harass crows, hawks and cats coming near his throne in an apple-tree. Southern farmers declare him a ''bee-marten,'' but he does not deserve the charge that he injures their hives. Laymen speak of the small, woodland flycatchers as ''pewees'' —a rough imitation of their plaintive calls; but the phebe (not Phoebe) and the chebéc call their names clearly, asserting their individuality. Another and different sort of flycatcher, however, the *Scissortail,* exists in the Texas region. It is a beautiful white, pink-trimmed little creature, with a distinguishing ornament in the two central tail-feathers, each eight to ten inches long, that float behind it as it flies. They spread and close at will, and do suggest the opening and shutting of a pair of scissors.

The word *Swallow* has suffered only trifling change from its ancient Scandinavian source, which seems to have been an attempt to express the swallow's swinging, to-and-fro, manner of flight—a "tossing" as of a ball by two players. The many northern species are designated, some by color, others by habits, and do not need explanation except, perhaps, as to the name *Martin,* which some of them bear. This term is an interesting introduction from France, and belongs to European history, for it recalls that good bishop of Tours (fourteenth century) who has become the patron saint of France. His feast-day, called in England martinmass, is on November 11, by which date most other small birds have fled toward the south, but this household swallow remains, as if to participate in the day of honor and so has come to be known as St. Martin's bird. It is not surprising that this insect hunter should stay late in France, for in southern Europe this is the pleasant season of the year that the French call St. Martin's summer and we Indian summer. Our large and friendly swallow, the "purple martin," has inherited the name, if not the pious repute.

Most of us would declare offhand that our bluejay is so called in imitation of its raucous shout which cheers us in autumn, but that is a bad guess, like so much else in popular etymology. The family name *Jay,* as we have it, originated in Italy. Passing into old French as *gai,* meaning gay, it became modified in recent French and Middle English as *geai,* with the initial softened and replaced by *j*; but the Spanish *gayo* retains the hard *g.* The word is an adjective proper to a bird having as bright a dress and lively manners as belong to most of this conspicuous family. The proper name of our eastern American representative should be jay-bird or better jaybird (one word), as is the custom in the southern states. West of the plains many other species exist, each named from its color or habitat or in personal compliment—for instance, the long-crested or "Steller's" jay of British Columbia, first brought to scientific notice by William Steller, the earliest naturalist to visit the northwest coast

Of particular interest to northern residents is a rather distant cousin of the bluejay—the *Canada Jay* Unlike its gay southern relatives it is garbed in sober grays and shows none of their swaggering behavior or banditry, but in the friendliest way it seeks the camp of the lonely traveler in the forest and the dooryard of every Canadian lumberman or pioneer, to be welcomed as an amusing guest or playfully sworn at for its impudence. Hence has arisen a long list of nicknames—moose-bird, meat-bird, camp-robber, deer-hunter (California) *le geia du Canada* (Quebec) and most popularly, in and out of books, "Whisky Jack." The last epithet is an anglicized form of the bird's name among the Indians speaking in Algonquian language and varies with tribal dialects—in Náscapi "uscachon," in Montagnais "uiskestian" (Comeau), in Cree "wiscachon" or "wiskichannis," and so on. Pronounce any of them and you will not wonder that the explorers of the northern forests instantly twisted one or all of them into Whisky John and then improved it into "whiskyjack."

Nearly all the crow-tribe reveal their names in their hoarse croaking and cawing, regardless of our spellings. This fact is hard to recognize in such words as rook, chough, daw, disguising three common European members of this sable-suited family, yet they are traceable to primitive attempts to translate the utterances of these birds. Entirely different in origin is the Scotch and Welsh "corbie," which is now used for the carrion-crow, hated by farmers and gamekeepers for its destruction of young lambs, broods of game-birds, and its carrion-eating propensity. This opprobrious epithet was first given in very early times to the raven, and it came from the Anglo-Saxon root-word *gor* (gore) signifying clotted blood and hence filth, as of a dead animal; and when the persecuted raven had disappeared from most of Britain the name was attached to the carrion-eating crow, and sometimes to the gray-backed crow or "hoodie," which is not much better.

The name *Raven* is now generally believed to have its source in the ancient verb to raven, tear, despoil, thus identifying this ominous bird with the scenes of battle, rapine and death with which our ancestors were sadly familiar not so many centuries ago.

Three lesser British members of the Corvidae, the rook, chough (pronounced "chuff") and daw are also self-namers, the last-mentioned now usually referred to as "jackdaw" in a spirit of amused contempt, for the "jack" in its name means "little." English literature is full of references to these birds, which leads me to bring them into this essay.

In North America, besides our various crows and ravens, we have two nearly related species deserving notice—the *Magpie* and the American Nutcracker, the second popularly known in the West as Clarke's or, better, gray crow. The latter is an inhabitant of the Rocky Mountain region, and was named after Captain William Clarke, co-leader of the famous Lewis and Clarke expedition across the continent in 1804–6, whence the first specimen was brought to scientific attention.

"Pie" is an old word, not much in use here, applied to birds, flowers and so forth which show color in blocks of contrasted hues, that is, are not striped or mottled; such are said to be "pied," and the *magpie* is an excellent example. The "mag" part of its name is evidently a short form of the French word Margot, and is just a friendly tag like Tom-tit or Poll-parrot. Shakespeare uses it in *Macbeth,* III; 4:

> Augurs and understood relations have
> By magot-pies and choughs and rooks brought forth
> The secret'st man of blood.

I fancy, however, that in the minds of most Englishmen, and of ourselves, the "mag" is a rough abbreviation of Margaret, and the bird, whose associations, actual and mythical, are, to say the least, mischievous, is thought of as a demirep female-relative of Jack Daw.

All our blackbirds, orioles, meadowlarks, etc. (except the bobolink) of the family Icteridae, bear borrowed names. The blackbirds generally were at first styled "American starlings" and "troupials," the latter an anglicized word meaning flockers. These were book-names, but practical farmers knew them as "corn-thieves," "redwings," "yellowheads," and called all the bigger kinds "crow-blackbirds" or "grackles." A recent author tells his readers that the *Grackle* came to be so called on account of its harsh voice, but this is a mistake; that word is a clipped form of the ancient Latin name of the jackdaw. Early European ornithologists transferred the generic term, as *gracula,* to the starlings of India, particularly the sacred myna of the Hindoos, and early American writers borrowed the term for use here when our blackbirds were mistakenly classified as starlings.

The true *Starling* (European), which is fast becoming naturalized among us, brought its name with it, which is a diminutive form of the Anglo-Saxon *staer* modified at first into "stare" (still used), and then into "sterling" and finally starling. Its nearest native counterpart in this country is the *Meadow*- or old-field lark. This bird is not at all a lark, however, although similar to one in habits and voice, and in the mating season often may be seen and heard flying high in the air over its nest and singing to its mate as if it really were a large skylark.

This brings us to the *Oriole* group, whose name has come to us by way of the French from the Latin *aureus*, golden, so that when some one speaks of our favorite summer visitor as "golden oriole" he is, as it were, painting the lily; to say "golden robin" is bad in another way. Our American orioles belong to a different family from their namesakes in Europe and the East, in spite of close external resemblance. Our most familiar "hangnest," at least in the eastern provinces, is the Baltimore oriole. This species owes its name to the great systemist Linnaeus, who desired thus to compliment Lord Baltimore, founder of the colony of Maryland, from which that naturalist had received a specimen-skin. Linnaeus regarded the bird as uncatalogued, and therefore, in 1766, named it *Oriolus Baltimore,* in allusion to that gentleman's ancestral colors, yellow and black; but Mark Catesby had described and pictured it long before (1731) in his book on the Carolinas under the name Baltimore-bird, bestowed for the same polite reason! Bullock's oriole represents almost exactly the Baltimore-bird on the Pacific Coast, and is a great favorite in California.

Bobolink got its cheerful nickname from the attempt of New England colonists to capture its song. Some Puritan ear happily caught these syllables, and everybody adopted them as they do a "catchy" tune. Nuttall and other ornithologists have devoted pages of their books to imitations in print of the merry fellow's tinkling prattle, only to show that words and syllables can't do it. It is the jazz in the spring concert. Some poems have come nearer to expressing the jolly melody, notably one by J. T. Trowbridge. When the meadow-courtships are done with, the resulting eggs hatched, and the black-and-buff uniforms of the erstwhile singers have become rusty brown by wear, the bobolinks and their families drift away southward to become "reed-birds," shot along the southern coast by hundreds of gunners (but less than formerly). After running this gauntlet the depleted flocks move on to the few remaining rice-fields, where, as hated "rice-birds," they are so persecuted that relatively few of the little migrants ever live to reach the safety of winter quarters in South America.

Babes in the Wood

Now we must give a little space to a company of small, distinctively woodland birds often seen together—a related, cooperative group of insect-hunters and caterpillar-catchers familiar to all observers in rural districts—titmice, nuthatches and creepers, with which may here be associated, for convenience, gnatcatchers, kinglets and dippers.

Titmouse. Tit is an ancient word for "little" (A. S. *tita*), particularly indicating a tiny bird; hence "titling" (the British hedge-sparrow), titlark, etc. The second syllable, mouse, simply indicates the grayish color and mouse-like behavior of the small and active birds that bear it. To carry this whole name into a plural tit-*mice* is, however, very misleading, for it turns the birds into "little mice"—which they are not! Undoubtedly the plural form should be titmouses—but it is too late (and awkward) to make it so, and it is best to forget it and call the whole tribe *Chickadees,* which they themselves ask us to do in their cheery calls to one another. This call, in the case of western species, is less distinct than is heard in the East, so that Californians call them "Bush-tits," and the related, yellow-headed bird in Arizona gets the Spanish name *Verdin* in reference to its greenish-ashy dress.

Nuthatch, i.e., nut-hacker, is borrowed from abroad, where it is much more applicable to British than to American species.

The *Brown Creeper* of our woods bears a name perfectly descriptive of this silent little creature as it travels mouse-fashion up and down the tree-trunks, exploring every crevice for insects and their eggs.

Gnatcatchers are in habits southern flycatchers.

Kinglets, the smallest American insect hunters except the hummingbirds, appropriately wear a half-hidden "crown" of golden or ruby feathers in each of our two species.

The American *Dipper* ("diver") or *Water Ouzel* (water-thrush) is practically the same as the European bird of that name, but its habits are different from those of the foregoing tree-haunters. It is numerous among all our western mountains wherever streams flow, near which it passes most of its life, its exquisite, prattling song charming all listeners.

Wren is almost unchanged from the oldest usage and spelling traceable, and only two of our eastern specific names call for notice—one is Bewick's wren, discovered and named by Audubon after Thomas Bewick (1753–1828), the famous English artist and engraver; the "winter" wren was so called because Wilson, Audubon and the early-describers, generally, lived in the southerly parts of the United States where it was visiting migrant from the North. Next to the almost universal "house wren," the "Carolina" or "mocking" wren of the southern states most deserves remark, as it stands as intermediate between the little wrens proper and their larger relatives—the mockers of the allied family Mimidae, embracing the celebrated *Mockingbird* of the South, the widespread mewing *Catbird* and the big *Brown Thrasher.* All three are magnificent singers, and we used to call them thrushes until the anatomists interfered. Whether any of them are really self-conscious mimics is still a matter of dispute in which this writer inclines to the negative side of the argument.

Thrush is a word of unremembered origin which appears in various forms in every Indo-European language. An ancient variant survives in "throstle," common in England for the song-thrush (German, *drossel*), which in Scotland is known as mavis, said to be of Spanish derivation.

Turning to American thrushes, I have not been able to discover what imaginative person gave the adjective *Hermit* to that adored songster, but probably he was among the readers of Alexander Wilson's "Ornithology," in which this thrush was first really described, although the bird had been noted in Carolina by Catesby (1731–48) somewhat earlier, under the name "little thrush." "The dark, solitary cane and myrtle swamps of the Southern States," says Wilson, "are the favorite haunt of this silent and recluse species." Therefore he introduced the new species as *Turdus solitarius.* The names of few other thrushes need remark: "Veery" is an expressive label to the distinctive character of its sweetly rolling music; Bicknell's thrush commemorates E. P. Bicknell, a naturalist of the Hudson River group; "varied" thrush is the book name of a Pacific-coast species better known as Oregon robin. A thrush in the West Indies, and another in British Columbia, noted for wonderful voices, are called "solitaires" because of their shy residence on remote mountains, and the *solo* method of each of these musicians. The best known of all, and most often seen and heard, the big, arrogant red-breasted eastern thrush—the *Robin*—now awaits his cue to appear.

Wherever an Englishman settles he

must have a "robin"—and science be hanged! When he set foot in Massachusetts or Virginia and was met by a bird with a reddish front he just naturally dubbed it robin in fond recollection of the little redbreast or ruddock in the gardens beyond the sea. But what about this recklessly used vocable? A moment's reflection reminds us that it is a Scottish diminutive, or pet name, for Robert, which has been borne by innumerable men ever since Robert the Bruce glorified British history in the fourteenth century. But boys were christened Robin long before the Bruce, notably that famous and popular (albeit somewhat mythical) outlaw, Robin Hood. It is certain that many garden plants have been named after that picturesque freebooter. "We have Robin flowers," the Reverend Henry Friend records, "and Robin's eyes, and poor Robins, as names of flowers chiefly, and herb Robert; but often these flowers are called Robin Hoods." This author gives us, in his "Folklore of Flowers," many further particulars, and expresses the opinion that the English redbreast is called Robin in memory of the romantic hero of Sherwood forest, although the only resemblance between bird and highwayman is that line in one of the old ballads celebrating his adventures thus:

> He wente hym full merry synging,
> As men have told in tale.

Waxwings could hardly escape their name if they desired to, for they wear a distinctive badge in the "red-sealing-wax" tips of the shafts of wing and tail quills. Two species of the family belong to North America. The lesser and more numerous is the familiar cedar bird or cherry bird, indicating its fondness for the fruits of those two trees, and of many others less conspicuous. The other and larger species is the "northern" or "Bohemian" waxwing, which has a circumpolar distribution, and rarely comes as far southward as the United States even in midwinter. An odd bit of history is connected with this bird's book-name. Nobody knew until recently where or how it dwelt or nested in summer, and in Europe in former days its irregular appearance in winter caused fear among the superstitious peasantry that it portended evils to follow. Some said that it came from Egypt or perhaps from Turkey; the general opinion likened its invasions to Gypsy wanderings, and Gypsies were thought in those days to be Bohemian. So the bird came to be called Bohemian waxwing. This queer name has followed it to America, where about a century ago the mystery of its sub-Arctic career was revealed by Canadian explorers of the fur-countries.

Vireo is one of the few instances in which a bird's scientific name has become its "common" one. The word is New Latin for greenness, and attempts have been made to popularize it as "greenlet," but they have met with little literary success. We have several species, all plainly labelled. The vireo family is exclusively American and abounds in the western Tropics, where various of its members have received nicknames suggested by their sharply uttered call-notes, such, in Jamaica, for instance, as "johntowhit."

Transference of name from one bird to another is a frequent and confusing accident. *Shrike,* for example, comes from an ancient verb "to shriek," according to Skeat; and William B. Cabot tells us that it is actually called "shrieker" in Labrador; yet, says Professor Newton, the birds that bear it have been so known in English only since about 1840. The name originally belonged in Scandinavia to a local jay, and was applied in England, after the career of the Danes there, to the mistletoe thrush (or storm-cock), still provincially known as the "screech-bird." H. K. Swan discourses learnedly on this subject in his dictionary of folk-names of British birds. We Americans usually speak of our shrikes as "butcherbirds" because they carry their prey to a tree-crotch or impale it on a thorn, etc., and eat it there at leisure or leave it for another meal—often forgotten. Germans call these birds nine-killers—just why, Ich weiss nicht!

To say simply that a warbler is a bird that sings prettily is not definite enough for the present purpose. We mean by it one of the exclusively American family *Mniotiltidae,* the Wood Warblers. Even so the name is not quite good and true, because almost none of these delightful little creatures warble, in any proper use of that verb. My idea of warbling is exhibited in the sweet, chattering song of our house-wren.

It is now my business to tell to what circumstance various wood-warblers owe their common names. Some species owe it to prevailing color, as "caerulean," "bay-breasted," etc.; others to chosen haunts, as in the case of "prairie," "palm" and the like. These need no comment. Several, however, have names that it will be well to explain. "Prothonotary," for example, was settled long ago upon a yellow warbler of the Southern swamp-lands; this is the title of a court officer, and why that early ornithologist Latham applied it to this innocent bird is inscrutable. Swainson's warbler (and hawk) was given as a compliment to another British naturalist who visited America early in the nineteenth century. Bachman's warbler recalls a Charleston physician who assisted Audubon; Lucy's implies a compliment to the daughter of Professor S. F. Baird, and Grace's to a sister of Dr. Elliott Coues—both men famous naturalists of the eighteenth century. In the same way certain warblers were named after Mrs. Blackburn (an English lady), J. K. Townsend, a companion of Nuttall's western researches, Dr. Kirtland, of Cleveland, Ohio, and in honor of the two celebrated ornithologists, Alexander Wilson (1766–1813) and J. J. Audubon (1780–1851).

The lovely Wilson's warbler of the older books is now listed as "the Canadian" because peculiarly at home there and easily recognized by the necklace of black beads across its golden breast. "Redstart" means red-tailed, from the Anglo-Saxon *steort,* tail. "Summer yellowbird" is a half-forgotten name of the purely lemon-yellow warbler of our gardens, to distinguish it from the black-winged yellow male goldfinch or "wild canary." The yellow-rumped warbler, conspicuous in early autumn, is now generally known as *myrtle-bird,* due to the fact that in winter it feeds in large flocks on the fruit of the bayberry bushes of the southern coast-region, there called myrtle trees; but lately hordes of pugnacious and greedy starlings have despoiled these trees of much of their crop and so persecuted the warblers that the very existence of the yellow-rumps as a species is threatened.

A group of three kinds of warbler-cousins must not be forgotten. These are the *water-thrushes,* a suitable name, for they look like the diminutive thrushes, and are especially fond of woodland water-courses. One of the three species, however, is very numerous everywhere in summer, and listed as "golden-crowned thrush," or more commonly as "oven-bird," because of the domed shape of its nest, made on the ground among thickets. These water-thrushes are the only real singers in the family, and resemble in several particulars the wagtails and pipits of the Old World.

There remains to be considered in this name-tracing search through the roster of American field and forest birds only one section—that of the *Sparrows* and their allies, constituting the cone-billed, seed-eating family Fringillidae. Having disposed of this extensive but etymologically rather uninteresting group we shall be able to pay attention to the Water Birds.

The general term *Sparrow* is as old as anything in English, and has suffered very little change from its prehistoric form developed from a northern stem, *spar,* that is said to contain the idea of "fluttering activity," so characteristic of these restless hoppers; not all etymologists, however, accept this derivation. Among the North American species of this family few require much explanation of their visiting-cards. The Savannah sparrow was so called by Wilson from its frequenting, as he says, "the low countries on the Atlantic coast from Savannah where I first discovered it." The Georgian river and city were bordered by extensive level meadows, which the Spanish explorers styled "savannas"; in the same way we get "prairie" from the French. The *yellow-winged sparrow* gets its nickname "grasshopper" from its buzzing little song. Our word "chippy" is a mispronunciation of chirper. The *fox sparrow* is chestnut, not foxy red; and the *whitethroat* is more noted for its voice than its color. The *white-throated sparrow* was the "nightingale" of early settlers in Quebec; and in Nova Scotia it has become "Poor-Kennedy-bird," recalling a legend of a certain Kennedy who was lost in the forest and imagined the bird as condoling with him. In New England everybody knows it as "Peabody bird," believing it especially numerous about Peabody Glen in the White Mountains, and many farmers will tell you that in spring it says: "Sow wheat, Peabody, Peabody." Of all the versions of the whitethroat's appealing chant I like best the one prevalent in Ontario, where it seems to sing "Sweet Canada, Canada."

With the first sign of winter storms there appear in the United States from the North small, plump "ground-birds," dark slate-color above sharply contrasted with the white of the breast. Every one used to call them simply *snow-birds;* but the somewhat elevated tribe of "bird lovers" have taught us to say *junco* instead—that is the generic name of the species. The change is rather convenient, especially in the northern parts of the bird's specific range, for it separates this winter migrant from the proper white snowbird, or "snowflake," great flocks of which come down with the snow-drifts into Canada, but of which we see few south of the Great Lakes.

Bunting. In the first general books on our avifauna, these snowflakes, the bobolink and some other fringilines were classed as "buntings," a word that hardly exists here. Among them was a familiar pasture-loving sparrow, marked by the white margins of the tail. It used to be cataloged as bay-winged bunting, but Wilson Flagg made a happy change from this to *vesper bird* indicative of its distinctive habit of singing in the evening dusk. The origin of "bunting" is unknown. Wright wrote in his *Lyrick* in the year 1300:

Ich wold Ich were a threstelcok,
A bunting or a lavercok.

Of the many guesses I like best my own, particularly as later I found it supported by the great Oxford Dictionary. Among country people, even now, a short-tailed, stocky chicken is called a "bunt," as it has been from time immemorial. The buntings are notably round and plump as compared with most other small song-birds, and "bunting" or "buntlin," diminutives of bunt, I believe to have been given them in reference to this appearance. How long ago did mothers begin to sing, "Bye, baby bunting, father's gone a-hunting?"

Another group of the Fringillidae contains the finches (German *fink*) of which we have such representatives as the goldfinch, indigo-bird and pine-finch.

The goldfinch is the black-capped yellow-bird, thistle-bird, lettuce-bird or wild canary of our gardens. (The original "canary" by the way, was a greenish and yellow native of the Canaries, Madeira and Azores. Examples were carried from the Canary Islands to Europe in the sixteenth century, and soon became so much in demand as cage-birds that the species was rapidly exterminated in its home.) The pine-finch is often listed as a "linnet." The true linnet is the European "flax-bird" as indicated by its ancient German name for flax, kept in our language in such terms as linen, linseed, etc., and in the Swedish family patronymic Linne, Latinized into Linnæus. Our redpolls are its near cousins. The pine-finch is also known as "siskin," a Norse word for any small songster, and thus a relic of the Danish influence on English speech.

Most of the other members of the Fringillidae family need little or no explanation. Of the names given to our various grosbeaks only one deserves serious attention—that of our wandering winter visitor whose large size and handsome yellow and black plumage makes it particularly noticeable. In the books it is listed as "evening grosbeak" (yellow or western grosbeak would be better), which came about by an odd error. Its first describer, knowing that his new species came from the Columbia River region, intended to label it "western," in Latin *vespertina;* but unfortunately the first person who wrote about the bird in English understood this specific name as meaning "evening," a poetic application of the word more properly used, as already mentioned in our name vesper-sparrow.

The males, at least, of all the North American grosbeaks—the rose-breasted, the blue, the black-headed and the "redbird"—are dressed in rich colorings. The "redbird," that glory of the southern states, is more widely given the title of *Cardinal,* for its plumage is just that shade of crimson worn by those high ecclesiastics of the Roman hierarchy that have figured so strikingly in political as well as in religious history. He is rivaled in our woods only by the vivid scarlet and black of the northern tanager.

WATER-BIRDS

It has seemed best, for present purposes, to discard "without prejudice" the most recent scientific arrangement in classification, by which some groups of aquatic birds are intermixed with the terrestrial and arboreal ones; and instead to leave the land birds by themselves. Nevertheless, the succession of the divisions of water birds from lowest to highest in rank will be followed as given in one of the latest manuals, namely, Dr. P. A. Taverner's "Birds of Canada" (Ottawa, 1934). His arrangement requires me to begin with the loons and grebes and end with gulls.

Loon. A vague notion is held by many persons that this name for the great northern divers is somehow connected with "lunatic," because of the wild surroundings in which the bird lives, and its eerie cry; in fact, it is merely a mispronunciation of an Iclandic word still prevalent in the Shetland Islands. Its relatives, the *Grebes,* took their name in French from the crest that adorns the heads of several conspicuous species.

The various birds that get their living out of the ocean, and dwell on its shores include in their names antique forms, frequently unintelligible; many also are the product of vagrant fancies coupled with superstition. Masefield, the sailor-poet, knew them—

> Gonys and gullies an' all the birds o' the sea,
> "They ain't no birds, not really, said Billy the Dane.
> "Not mollies, nor gullies, nor gonys at all," said he,
> "But simply the sperrits of mariners living again."

Molly, short for "mollemoke" in various forms, is explained by Swann as an old Dutch-mariner's name for the fulmar, now corrupted into molly-mawk and applied to other oceanic species. It is on record since earliest British Arctic voyages, and remains in common use on Greenland waters and in northern Britain.

Of all these winged wanderers none is more mysterious than the *Petrel* to most of us; and a part of the mystery is in its name. Those who know the Pacific Coast variety of Leach's "petrel" might make a strong argument for its nocturnal cry as the name-source, but the voices of other species do not support this view. The traditional explanation is the one adopted by W. H. Hudson in his delightful little book "British Birds." "The name 'petrel,'" he says, "comes about in a very curious way. It is the diminutive of Peter, given to the bird on account of a habit it has, when gliding along just above the surface, of dropping its feet and paddling, producing the idea that it is walking on the water. I am not quite sure that this is a correct derivation; Peter (the apostle), it will be remembered, was not quite successful in his attempt to walk on the waves. Sailors call the petrels 'Mother Carey's chickens,' but not, as might be imagined from such a name, on account of any tender regard or feeling of affection for the birds."

Now who is, or was, this Mother Carey, whose chickens flock on the heaving ocean and play in the wild winds, so that the smaller sorts are dubbed "storm-petrels"? The great black fulmar petrel, which haunts the Cape of all Storms (as Vasco de Gama purposed to christen the tip of South Africa) is known as Mother Carey's goose! There seems to be no generally accepted picture of the lady in the minds of our northern folk or definite knowledge of origin or habitation. Some say she is a sort of marine witch and that the black little birds are her imps; others smilingly dismiss the matter by telling you that she is an aunt of Davy Jones!

But they know better along the shores or on the waters of the Mediterranean, and will assure you that she is *Mater* or *Madre* or *Madre cara*—Dear Mother (of Jesus), *Sancta Maria,* to whom all southern sailor-men breathe a prayer for safety when the clouds lower on the horizon and the flitting harbingers of gales so mysteriously arrive and cluster about the laboring ship; and French fishermen say the petrels are *oiseaux de Notre Dame*—birds of Our Lady. "Madre cara" might suffer a sea-change in the mouth of an English-speaking sailorman, its Spanish or Italian origin unheard or forgotten; but can you imagine a foremast-hand on a Liverpool limejuicer or a Gloucester fishing-smack breathing a frightened prayer to Mother Carey?

Related to and associated with the petrels are the huge *Fulmar* (origin undetermined), the "gony" of Dutch-seamen at the Cape of Good Hope, and the *Shearwaters,* whose skimming, twisting flight accounts for their name, among many nicknames. Here may as well be mentioned guillemots, puffins and murres, whose queer names are indefinable. *Pelican* is known to everybody, but why or when it came to be so called is still obscure. *Cormorant* is near-Latin for "sea-crow."

This brings us to the *Herons,* presumed to be so called in imitation of their hoarse cries. Dr. Skeat explains the familiar taunt "not to know a heron from a handsaw" by reminding us that the diminutive of the French *heron, heroneau,* was corrupted long ago in British speech into "heronsewe," this into "hernser" and this family finally mutilated into "handsaw"; similarly, *heronceau* became "heronshaw," an heronry. The short form "hern" is now only poetic, as in Tennyson's rippling line "I come from haunts of coot and hern." Our white herons are distinguished as egrets (also their exquisite plumes), derived from *heigir,* an old German word for heron. In the same family are the bitterns, storks and ibises. Bittern goes back to early Latin, but what it indicated is obscure; *Ibis* is of Egyptian stock; *Stork* seems to be Scandinavian.

Duck, an old Norse-English word, means diver. The names of few of the North American are in need of explanation. When we say "wild duck" we usually mean *mallard,* a shortening of the French word for a male duck, particularly the drake of this species. *Scoter* is a form of "scooter"; *shoveler* and *scaup* refer to the shape of their bills. *Gadwall, Pochard* ("poker") *Teal* and *Wigeon* are of ancient northern lineage. *Eider* is Dutch for fowl, but French Canadians call an eider "moyas," as learned by the first colonists from the Micmac Indians. A section of the duck tribe includes the fishing ducks or sawbills, goosanders and shieldrakes, under the group-name *Mergansers*—a queer invented combination of *mergus* and *anser* which equals "diving ducks." Sheldrake, locally heard, should be spelled "shieldrake," for it means a bird spotted in such a way as to suggest (at least in Great Britain) armorial markings on a knight's shield. A noisy species has the name *Old Squaw* in humorous reference to its squeals.

Strange to say no American bird north of Mexico officially bears the name it had in any Indian language, with the doubtful of two or three. "Waxy" snow geese (genus *Chen*) are generally known in northern Canada as "wavies," a mispronunciation of the Chipewyan (?) word *wawa;* and gunners about Lake Ontario call the noisy long-tailed duck "cowheen," variously spelled. I find a hint as to the origin of this queer designation in William Kirby's "Annals of Niagara," where the author, speaking of conditions about 1784, remarks: "The Niagara River was in the early spring covered with flocks of millions of that active noisy bird, the kaween, so called by the Algonkin name—the ice-duck or old man, so called. . . . They are now (1870) nearly extinguished in the Niagara River." Perhaps "sora," the little rail, might claim a place here.

Goose and *Swan* are nouns of ancient lineage in northern Europe. Of our wild geese the one best known to the public is the Canada goose or "honker." Several different geese are "brant," to sportsmen, from an old word "brent," burnt or charred. The genus *Branta* includes also the barnacle goose, taking its name from a fabulous belief in the middle ages of which I have given a rather full account in my "Birds of Legend, Fable and Folklore."

Swans, cranes and rails call for no notice here, except possibly in the case of the *Sora* (rail), whose name no doubt was learned from Indians.

Few avian groups are as numerous as that of the shore birds (Charadrii), and none presents such a bewildering multiplicity of popular names. The sandpipers, snipes, curlews, plovers, etc., are objects of sport all over the world, and local words and values vary endlessly. Some foreign names have been brought to America, and have been applied more or less accurately to our similar species. Swann's Dictionary of the sporting and folklore names of British birds requires 200 pages of space. From this and broader sources we learn that *Plover* is anglicized French, with the primitive significance of "rain," *i.e.,* a rainy-season bird. The *Dotterel,* one of the plovers, suffers under the imputation of being a "little dolt," because, like the "booby" gannet, "fool-hen" (spruce grouse), and others, it appeared stupid in the presence of danger. Old books give the dotterel this reputation. Kay (1570) relates that it is taken at night by the light of a candle, when it becomes absorbed in the actions of the fowler, "for if he stretches out an arm the bird also stretches out a wing, if a foot likewise a foot . . . and so, being intent on the man's gestures, it is deceived and covered with the net spread for it." The snipe *Dunlin* might well call itself "brownie." *Godwit* is perhaps "good wight" in the sense of excellent eating—at any rate Ben Jonson refers to it as a delicacy. *Dowitcher* is bad German, indicating belief in its German nativity. *Knot,* the sandpiper, is supposed to have furnished Canute with a favorite dish; hence that stanza in Drayton's "Poly-Olbion":

> The knot that called was Canutus bird of old,
> Of that great king of Danes, his name that still doth hold,
> His appetite to please, that farre and neare was sought,
> For him (as some have sayd), from Denmark hither brought.

Certainly it used to be netted in England in great numbers and fattened on bread and milk as a table delicacy.

Those Arctic seafowls, the *Auks,* interest us on account of the sadly romantic history of the extinction of the giant of the race, and the large present market value of the shells of the few great auk's eggs still in existence. The word "auk" has often been accounted for by connecting it with the awkward gait of the bird, but evidently it is only a rude pronunciation of the Iclandic name *alka* (whence the family designation, Alcidae). While the great auk still existed in northern and western Scotland and Wales, it was called gare or garfowl, or gairfowl, as we read in documents of ancient date; but the origin and meaning of these variously spelled terms remain disputable.

Gull is a bird-name unexplained by etymologists. I am inclined to think that its root might be found somewhere in the wake of such nouns as gullet, gulp, *et al.* The bird's foolish voracity in seizing and trying to swallow anything that falls in its way without examination accounts for the word "gullibility," to express too easy credibility.

WHAT IS CALCULUS OF VARIATIONS AND WHAT ARE ITS APPLICATIONS?

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THE calculus of variations belongs to those parts of mathematics whose details it is difficult to explain to a non-mathematician. It is possible, however, to explain its main problems and to sketch its principal methods for everybody.

The first human being to solve a problem of calculus of variations seems to have been Queen Dido of Carthage. When she was promised as much land as might lie within the boundaries of a bull's hide, she cut the hide into many thin strips, put them together into one long strip, the ends of which she united, and then she tried to secure as extensive a territory as possible within this boundary. History does not describe the form of the territory she chose, but if she was a good mathematician she covered the territory in the form of a circle, for to-day we know: Of all surfaces bounded by curves of a given length, the circle is the one of largest area. The branch of mathematics which establishes a rigorous proof of this statement is the calculus of variations.

Newton was the first mathematician to publish a result in this field. If a body moves in the air, it meets with a certain resistance, which depends on the shape of the body. The problem Newton studied was, what shape of body would guarantee the least possible resistance? Applications of this problem are obvious. The rifle bullet is designed in such shape as to meet with a minimum resistance in the air. Newton published a correct answer to a special case of this problem, namely, that the surface of the solid considered is obtained by revolving a curve around an axis. But he did not give the proof or the calculations that had led him to the answer. So Newton's solution had no great effect on the development of mathematics.

A new branch of mathematics started with another problem formulated and studied by the brothers Bernoulli in the seventeenth century. If a small body moves under the influence of gravity along a given curve from one point to another, then the time required naturally depends on the form of the curve. Whether the body moves along a straight line (on an inclined plane) or along a circle makes a difference. Bernoulli's question was: which path takes the shortest time? One might think that the motion along the straight line is the quickest, but already Galileo had noticed that the time required along some curves is less than along a straight line. The brothers Bernoulli determined the form of the curve which takes the shortest possible time. It is a curve which was already well known in geometry for other interesting properties and had been called cycloid.

What is common to all these problems is this: A number is associated with each curve of a certain family of curves. In the first example (that of Queen Dido) the family consists of all closed curves with a given length, and the associated number is the area of the inclosed surface; in the second example (that of Newton) the number is the resistance which a body somehow associated with the curve meets in the air; in the third example (that of the brothers Bernoulli) the family of curves consists of all curves joining two given points, and the number associated with each curve is the time it takes a body to fall along this curve. The problem consists in finding the curve for which the associated number attains a maximum or a minimum—this is the largest or the smallest possible value; in Dido's example, the maximum area; in Newton's example, the minimum resistance; in Bernoulli's example, the shortest time.

Some problems concerning maxima and minima are studied in differential calculus, taught in college. They may be formulated in the following way: Given a single curve, where is its lowest and where is the highest point? or given a single surface, where are its peaks and where are its pits? With each point of the curve or the surface, there is associated a certain number, namely, the height of the point above a horizontal axis or a horizontal plane. We are looking for those points at which this height is greatest or least. In differential calculus we deal thus with maxima and minima of so-called functions of points, *i.e.*, of numbers associated with points; in calculus of variations, however, with maxima and minima of so-called functions of curves, that is, of numbers associated with curves or of numbers associated with still more complicated geometric entities, like surfaces.

A famous question concerning surfaces is the following problem, the so-called problem of Plateau: if a closed curve in our three-dimensional space is given, we can span into it many different surfaces, all of them bounded by the given curve, *e.g.*, if the given curve is a circle we can span into it a plane circular area or a hemisphere or other surfaces bounded by the circle. Each of these surfaces has an area. Which of all these surfaces has the smallest area? If the given curve lies in a plane, like a circle, then, obviously, the plane surface inscribed has the minimum area. If the given curve, however, does not lie in the plane, like a knotted curve in the three-dimensional space, then the problem of finding the surface of minimal area bounded by the curve is very complicated. The question, which was solved some years ago by T. Radó (Ohio State University) and in a still more general way by J. Douglas (Massachusetts Institute of Technology), has applications to physics, for if the curve is made of a thin wire and we try to span into it a thin soap film, then this film will assume just the form of the surface of minimum area.

We frequently find that nature acts in such a way as to minimize certain magnitudes. The soap film will take the shape of a surface of smallest area. Light always follows the shortest path, that is, the straight line, and, even when reflected or broken, follows a path which takes a minimum of time. In mechanical systems we find that the movements actually take place in a form which requires less effort in a certain sense than any other possible movement would use. There was a period, about 150 years ago, when physicists believed that the whole of physics might be deduced from certain minimizing principles, subject to calculus of variations, and these principles were interpreted as tendencies—so to say, economical tendencies of nature. Nature seems to follow the tendency of economizing certain magnitudes, of obtaining maximum effects with given means, or to spend minimal means for given effects.

In this century Einstein's general theory of relativity has as one of its basic hypotheses such a minimal principle: that in our space-time world, however complicated its geometry be, light rays and bodies upon which no force acts move along shortest lines.

If we speak of tendencies in nature or of economic principles of nature, then we do so in analogy to our human tendencies and economic principles. A producer most often will adopt a way of production which will require a minimum of cost, compared with other ways of equal results; or which, compared with other methods of equal cost, will promise a maximum return. It is obvious that for this reason the mathematical theory of economics is to a large extent application of calculus of variations. Such applications have been considered by G. C. Evans (University of California) and in particular by Charles F. Roos (New York City). A simple but interesting example, due to the economist H. Hotelling (Columbia University), is to find the most economic way of production in a mine. We may start with a great output and increase the output later or we may increase the output in time or we may produce with a constant rate of output. Each way of production can be represented by a curve. If we have conjectures concerning the development of the price of the produced metal, then we may associate a number with each of these curves—the possible profit. The problem is to find the way of production which will probably yield the greatest profit.

In the mathematical theory of the maximum and minimum problems in calculus of variations, different methods are employed. The old classical method consists in finding criteria as to whether or not for a given curve the corresponding number assumes a maximum or minimum. In order to find such criteria a considered curve is a little varied, and it is from this method that the name "calculus of variations" for the whole branch of mathematics is derived. The first result of this method, which to-day is represented by G. A. Bliss (University of Chicago) and his school, was the equation of Euler-Lagrange, which states: A curve which minimizes or maximizes the corresponding number must in each of its points have a certain curvature which can be determined for each problem.

Another method consists in finding out quite in general whether or not a given problem is soluble at all. For example, we consider the two following extremely simple problems: two given points may be joined by all possible curves; which of them has the shortest length, and which of them has the greatest length? The first problem is soluble: The straight line segment joining the two points is the shortest line joining them. The second problem is not soluble: There is no longest curve joining two given points, for no matter how long a curve joining them may be, there is always one which is still longer. The length is a number associated with each curve which for no curve assumes a finite maximum.

This second method of calculus of variations was initiated by the German mathematician Hilbert at the beginning of the century. The Italian mathematician Tonelli found out twenty years ago that the deeper reason for the solubility of the minimum problem concerning the length, that is, for the existence of a shortest line between every two points, is the following property of the length: A curve between two fixed points being given, there are always other curves as near as you please to it, and yet much longer than the given curve (*e.g.*, some zigzag lines near the given curve). But there is no curve very near to the given curve and joining the same two points, which is much shorter than the given curve. This property of the length is called the semi-continuity of the length. Contributions to this Hilbert-Tonelli method are due to E. J. McShane (University of Virginia), L. M. Graves (University of Chicago) and to the author.

Another way of calculus of variations was started in this country. G. D. Birkhoff (Harvard University) was the first to consider so-called minimax problems dealing with "stationary" curves which are minimizing with respect to certain neighboring curves and at the same time maximizing with respect to other curves. While the minimum and maximum problems of calculus of variations correspond to the problem in the ordinary calculus of finding peaks and pits of a surface, the minimax problems correspond to the problem of finding the saddle points of the surface (the passes of a mountain). The simplest example of such a stationary curve is obtained in the following way: if we consider two points of the equator of the earth, then their shortest connection on the surface of the earth is the minor arc of the equator between them. There is, as we have seen, no longest curve joining the two points. But there is one curve on the surface of the earth which, though it is neither the shortest nor the longest one, plays a special rôle in some respects, namely, the major arc of the equator between the two points.

One of the greatest advances of calculus of variations in recent times has been the development of a complete and systematic theory of stationary curves due to Marston Morse (Institute of Advanced Study). The most simple example of this theory, which calculates the number of minimizing and maximizing curves as well as of stationary curves, is the following ''geographical'' theorem quoted by Morse: If we add the number of peaks and the number of pits on the surface of the earth, and subtract the number of passes, then the result will be the number 2, whatever the shape of the mountains may be (highlands excluded).

There are many technical details of calculus of variations which are hardly available to a non-mathematician. They are the type of theory which frequently leads to the belief that mathematical theories are remote from the urgent problems of the world and useless. Real mathematicians do not worry too much about these reproaches which are engendered by a lack of knowledge of the history of science. Mathematicians study their problems on account of their intrinsic interest, and develop their theories on account of their beauty. History shows that some of these mathematical theories which were developed without any chance of immediate use later on found very important applications. Certainly this is true in the case of calculus of variations: If the cars, the locomotives, the planes, etc., produced to-day are different in form from what they used to be fifteen years ago, then a good deal of this change is due to calculus of variations. For we use streamline form in order to decrease to the minimum possible the resistance of the air in driving. It is through physics that we learn the actual laws of this resistance. But if we wish to discover the form which guarantees the least resistance, then we need calculus of variations.

CHROMIUM

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THE old Egyptians and the ancient Chinese five thousand and six thousand years ago were well versed in the art of metals. They fabricated a wide variety of articles both of the general utility type, such as weapons and household necessities, and of the purely art type, such as statues, vases, jewelry, etc. But they were very limited in choice of metals to work with. Six thousand years ago there were only five metals known to man —copper, tin, gold, silver and lead. It was almost two thousand years before iron was added to the list. To-day we have at our command over seventy metals. The one metal which forms the very basis of our modern civilization is iron. The world to-day produces this metal at the rate of one hundred million tons per year. No other metal can compare in volume, in low cost, and in valuable mechanical properties. The next metal, as far as world's production is concerned, is copper, with an annual world's output of two million tons, that is, only two pounds of copper for every one hundred pounds of iron produced. The output of any of the other metals is less than that of copper.

The supply of lead and copper is alarmingly limited in comparison with that of iron. At the present rate of consumption we would exhaust our lead and copper mines in less than one hundred years.

Iron builds our bridges and skyscrapers, subways and steamships, railroads and automobiles and machinery in general—besides millions of small articles ranging from the farmer's scythe to the woman's needle. There are a number of fortunate circumstances that give iron this domineering position in our modern industrial structure: First of all, the supply of iron in the earth's crust is almost limitless; secondly, the methods of converting iron ore into useful steel are relatively cheap; thirdly, the mechanical properties of the various iron products are superior to those of other metals.

Yet with all the outstanding advantages of iron—its low cost, its strength and its vast supply —it has one very serious weakness: It does not withstand weather conditions in those localities where it is most needed. The more dense the population of any area the more rapidly will iron rust or corrode.

Exhaustive investigations carried out in the foremost laboratories all over the world, seeking to find the best method or means of counteracting the corrosion of iron and its economic waste of $3,000,000,000 a year, finally led to a solution—the addition of another metal to iron. This metal is chromium. Chromium added to iron makes it rustless, stainless. It is less than a generation ago that our civilization received one of the greatest gifts of all times from the metallurgical laboratories—stainless steel.

Why, you might inquire, was the discovery of stainless steel of such recent date? Although chromium has been known to the metallurgist since 1797, it was not possible to produce stainless steel before the advent of electricity and the electric furnace, which furnished the necessary high temperatures impossible of attainment with wood- or coal- or oil-fired furnaces.

The metal chromium was discovered by a French chemist, Vauquelin, in 1797, and since various chemical compounds of the metal were beautifully colored—orange, yellow, blue, green, etc.—he called the new metal chromium from the Greek word chroma, color. The emerald owes its green color to chromium, the ruby its red and the sapphire its rich blue color. Chrome green is the best and most permanent green pigment we

Whereas it is comparatively simple to obtain tin or lead or copper from its ores, the recovery of chromium in a relatively pure state is much more difficult, and on this account over a hundred years elapsed, after Vauquelin's discovery, before the metal entered the commercial field.

It was not until the arrival of the electric furnace about thirty years ago that the problem of making chromium metal and chromium alloys was commercially solved. Hundreds of important chromium alloys are made electrically to-day: Without these chromium alloys the modern automobile would be impossible. Our food, oil, paper and other chemical industries are very much dependent upon chromium steels. Chromium alloys for airplane parts that resist corrosion, for armor plate that defies the best piercing shells, for high-speed tools that turn out thousands of products as against dozens with the old steel tools without chromium, for the heater wire that toasts your bread at breakfast and the knife that cuts the bread, the best ball bearings, the Zephyr of the Burlington Railway and the Flying Yankee that rushes you from Boston to Bangor are built entirely out of chrome steels.

The most important of chrome steels

is the so-called 18/8, that is, 18 per cent. chromium, 8 per cent. nickel and the balance chiefly iron. Over half of the chrome steels produced to-day are of this 18/8 type. And these are the steels that interest the architect in particular. The Chrysler Building and the Empire State Building have consumed many, many tons of this bright, shiny, rust-defying alloy of chromium. It is as strong and tough as the best of the older steels made without chromium. The rapid spread of the application of this stainless steel or 18/8 alloy in the modern building has been most phenomenal: Store and window fronts, massive entrance doors and grill work, interior arch trim, ceiling and corridor trim, lighting fixtures, staircases, guard rails, step plates, escutcheons, door plates, elevator doors, window fittings and many more.

Stainless steel is easily workable—can be drawn, spun, machined and welded. The most complicated architectural designs are faithfully carried out. The metal has an attractive permanent luster. All maintenance expense, such as for painting ordinary steel, which runs into thousands of dollars, is entirely eliminated. More than 100,000 square feet of polished stainless steel trim cover the exterior of the Empire State Building that will never need painting.

The higher the chromium content of the alloys the more resistant to corrosion. Accordingly, the question might arise: "Why use chromium alloys, why not chromium metal itself?" The answer to that is that we have not yet learned how to produce chromium metal as cheaply as iron, nor have we yet learned how to produce malleable sheets of chromium metal, although the metal is inherently ductile. We have met the situation in one way: We have learned how to apply a surface of pure chromium on iron, steel, brass and other metals: In other words, we can electroplate pure chromium metal on iron and in that way protect the iron from corrosion. You are all too familiar with chrome plate, so we need say very little. It may interest you to know that we can chromium-plate aluminum and zinc-die-cast metal. And we can color chrome plate—"chromed chrome," so to speak. The life of printing plates, chromium plated, has been extended a million fold due to the extreme hardness of chromium. The fine needles that knit the sheer hosiery of our ladies are chromium plated to prevent any rust spots. Automobile jewelry, bathroom fixtures and numerous other articles are regularly chromium plated to-day. Chromium plate is better than nickel or zinc plate, because it is more resistant to both wear and corrosion. And it will not tarnish or react with sulfur, as does silver. Accordingly, the molds for rubber tires and other rubber goods are made of chromium-plated steel.

The quality of the plate will decide the life of the chromium-plated article. You can not estimate the thickness and quality of chromium plate by mere visual inspection. Accordingly, it is important to have your chromium plating done by a reliable concern that will apply the proper thickness of plate free from flaws.

In conclusion, may we emphasize the very important rôle the metal chromium is playing in the new post-war civilization: Due to its outstanding properties of corrosion- and wear-resistance it has made a vast number of products and processes, structures and speeds possible—some of which were not even dreamed of a few years ago.

SURVEYING THE BUTTERFLIES OF VIRGINIA

By AUSTIN H. CLARK

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OVER one hundred years ago Drury, Cramer and Boisduval and LeConte mentioned, more or less incidentally, quite a number of butterflies as occurring in Virginia. Since their time only a few scattered notices of butterflies from that state have appeared in print. So, as I live in Washington, am too young for golf, too old for tennis and too lazy for hunting, it occurred to me that it might be worth while to undertake a detailed survey of Virginian butterflies.

It may be of interest to explain briefly how I am going about the job of making a survey of the butterflies of Virginia. The equipment consists of Henrietta, a very ancient though still more or less reliable Ford, nets, jars, etc., paper, pencils and a wife to operate the pencils. As I drive along all the butterflies seen are noted and recorded by the wife. From a car moving not too rapidly—and Henrietta can't move too rapidly—it is possible to distinguish all the larger butterflies, swallowtails, pierids, the larger nymphalids and others. Every once in a while I stop and look for the smaller field-inhabiting species along the roadside or for the wood-loving species in the woods. Bogs, marshes and other likely places engage my more serious attention.

Gardens are always well worth visiting. The technique of examining a garden is simple. You send the wife up to ask the proprietor if you may have the pleasure of admiring the lovely flowers. He or she always says "Yes." Then, with the trusty paper, pencil and wife, you praise his or her skill in making flowers grow, at the same time murmuring apologetically and enviously about the sad results you have had in trying to coax flowers from the ground in a city back yard with a soil composed of fragments of bricks in a matrix of sterile blue clay. By following this method you can get in half an hour a complete list of all the commoner flower-frequenting butterflies in the neighborhood without raising any horrid suspicions as to your sanity.

Whenever I stop, Henrietta's radiator always engages my attention. You have no idea what a good little bug-catcher Henrietta is. The bees and wasps come in and circulate mainly about the passengers on the back seat. But the butterflies stick to the radiator. Once in Georgia Henrietta succeeded in catching a species I never caught with my net.

This reminds me that if you are to make a really accurate survey of the butterflies of any area under modern conditions you must develop a sort of instinctive corpse-consciousness. As an illustration of what I mean, not long ago one of my friends in Washington brought in a butterfly new to the fauna of the District of Columbia that he had picked up on Constitution Avenue. It was a specimen of *Danaus berenice.* Holland gives the habitat of this species as southern Texas, Arizona and southern New Mexico. But if you keep your eyes open you will soon learn that it is common in Florida and ranges northward to southern North Carolina. I was loath to sadden my friend, but the frayed remnant of a New England conscience asserted itself, and I told him his specimen had undoubtedly dropped off the radiator of a car from Florida.

Certain species are more easily found as caterpillars than as adults. This is especially true of the little dark brown pigweed skipper, *Pholisora catullus,* and the turtle-head butterfly, *Euphydryas phaëton.* So pigweed is always examined for the shelters of this little skipper, and the turtle-head, *Chelone glabra,* is always gone over carefully for the webs of the social caterpillars of the turtle-head butterfly.

By taking road records in this manner it is surprising how much territory one can cover. All the accumulated information is useful in determining general distribution, relative density of population in various regions and time of appearance in different sections of the state.

I have visited all the one hundred counties of Virginia, most of them several or many times. I try to time my successive visits to each county so as to be there at different seasons in successive summers. From now on my work will be more or less concentrated in certain strategic areas, particularly the coastal plain, the mountains, and isolated swamps, marshes and bogs.

Geographically, Virginia seems to have been a somewhat indefinite concept in the minds of a number of eminent lepidopterists. So we find listed as from Virginia butterflies whose place of origin was the Virgin Islands, Virginia in southern Brazil, Virginia City, Nevada, and West Virginia. A Philippine species is mentioned from Virginia through having been originally described, by error, from West Virginia.

The bursting of these geographical bubbles leaves us with a substantial body of 132 species and subspecies definitely known from the State of Virginia, of which I have taken personally 125. There are also 132 species known from New York State. But there is an important difference between the number recorded from New York and the number recorded from Virginia. From New York we know practically all the species that should occur there, together with a few that have no business there, while no less than twenty-five species occur both north and south of Virginia but have not as yet been taken within its borders, or else occur in its immediate vicinity, as for instance at Cabin John, Maryland, on the north bank of the Potomac, where *Incisalia henrici* and *Atrytone bimacula,* unknown from Virginia, have been found. Four species credited to Virginia, undoubtedly correctly, have not been found in the state within the past one hundred years. I am willing to bet that they will not succeed in eluding me much longer. Have I any takers?

Virginia is divided into four faunal areas. First, there is the Canadian zone represented by more or less isolated islands on the high mountain tops in the southwest. The one characteristic butterfly here is a dark southern form of the green comma, *Polygonia faunus smythi.* It is a pleasure in midsummer to hunt for this butterfly along the roads through the cool red spruce or lashorn forests at 5,000 feet and then in the evening write post-cards to your friends in Washington telling them you are looking forward to getting down into the lowlands where you can get warm again.

The mountain country in the western part of Virginia belongs to the Transition zone. Characteristic of this zone within the state are *Argynnis aphrodite, A. bellona, A. myrina* (which is very local), *Euphydryas phaëton, Polygonia progne, Glaucopsyche lygdamus* (which is by no means so rare as it is supposed to be), *Incisalia augustinus, Pyrgus centaureae* and a few others. You can find all these except *Argynnis myrina,* an inhabitant of wet grass lands, along the Skyline Drive.

A few words regarding *Pyrgus centaureae* may not be out of place. This little gray and white skipper has a most deplorably unethical concept of its zoogeographical responsibilities. It occurs in the mountains of Scandinavia and of central Asia, and in North America is found in the Hudsonian zone in Labrador, British Columbia, the high mountains of Colorado and elsewhere. It is found in the Canadian zone in Quebec and in the Transition zone, intruding into the Upper Austral, from New Jersey to North Carolina. It is absent from New England, and has been recorded only from the extreme north and the extreme south of New York. Can you imagine any living thing so callous toward culture and so scornful of industrial initiative and energy as almost ostentatiously to omit from its range New England and New York? In one respect, however, this little butterfly is quite consistent. No matter where it lives it always flies in the same temperature. So in Norway and in Labrador you see it flitting about in midsummer, in Virginia only in early spring.

In Virginia the Upper Austral zone occupies a rather narrow strip along the eastern foothills of the mountains and enters the southern part of the Shenandoah Valley. So far as butterflies are concerned it is a zoogeographic myth. Perhaps *Phyciodes nycteis* belongs to it, but if it does its one idea seems to be to escape from it, for most of the records are from the Transition or Canadian zones.

Approximately the eastern half of the state belongs to the Lower Austral zone. This is an extraordinarily interesting region, and when you are in it you yourself often become an object of intense and practical interest to its numerous anthropophagous arthropodous inhabitants. For on a very hot day in the great coastal swamps you deliquesce into a sort of stew greatly appreciated by dipterous demons of many sorts and also, I may add, by certain butterflies.

It is unfortunate that the butterflies have not as yet learned their responsibilities in regard to the Lower Austral zone. Their contemptuous disregard for the excellent work of the Biological Survey is as disconcerting as it is unethical.

In the Canadian and Transition zones the majority of the butterflies you see, especially in late summer, are not strictly confined to those zones; but although their distribution is not strictly coterminous with the life zones, it falls within more or less definite limits.

In the Lower Austral zone the sit-downers appear. These sit-downers are species, usually from the Transition zone, that occur in localized areas far from their normal, or perhaps I should say orthodox, habitat.

Most spectacular of these sit-downers is that finest and most magnificent of all the fritillaries, *Argynnis diana*, the great desideratum of all amateur collectors and the great joy of the get-rich-quick type of entomological dealer.

Argynnis diana was described by Pieter Cramer from Virginia in 1779. It was next reported from Virginia 116 years later, this time from Blacksburg in the mountains. Nineteen years later Professor Ellison A. Smyth, Jr., wrote that he had found it in Montgomery, Washington and Giles Counties, all in the mountains. I have personal records of this species from nineteen additional localities, from Bath County southwestward and as far east as Bedford and Patrick Counties. I thought I had put this insect in its proper place as an inhabitant, in Virginia, of the Transition zone, occurring chiefly at considerable altitudes.

Imagine my consternation, therefore, when my young friend, Mr. Carroll M. Williams, of Richmond, produced specimens last summer from Zuni and New Bohemia on the Blackwater River in the heart of the coastal plain. When my mind began to recover from the shock—the idea of beautiful *diana* living in those awful coastal swamps would be a shock to any one—a new light began to dawn upon me. It became clear how Cramer was able to secure the specimen, he described and figured 158 years ago. His collector probably captured it in the swamps of the thickly settled coastal plain.

Furthermore, other things became clear. I had been much astonished to find *Satyrodes eurydice*, so characteristic of grassy bogs in New England and Canada, in a swamp on the Meherrin River near Emporia, and *Argynnis cybele* at Zuni, at almost the same spot where Mr. Williams took *diana*. This last, perhaps, is not so strange, for *cybele* is very active, and I have a record from Northampton County on the Eastern Shore. But I had found *Satyrodes eurydice* previously in Virginia only just across the Potomac from Washington in Arlington and Fairfax Counties, and at Burkes Garden in Tazewell County in the southwestern mountains.

Quite as strange is the wholly unorthodox behavior of the two forms of the swamp skipper *Atrytone dion*. Two years ago I captured thirty-six specimens of this in the Dahl Swamp in Accomac County. These represented the dark southern form called *alabamae,* known previously from one male and two females from near Mobile, Alabama. Last summer I caught some more in the boggy hollows among the sand dunes just west of Cape Henry. But these represented the northern brightly colored form, not the dark southern form I had captured in the Dahl Swamp further north. Specimens from North Carolina also represent the northern, not the southern, form.

There is a simple explanation for the occurrence of Transition zone butterflies in localized regions in the coastal plain. The western border of the Dismal Swamp and the swamps of the Blackwater, Nottoway and Meherrin Rivers are fed by cold ground water that oozes from the porous soil. The same is true of the boggy hollows near Cape Henry. In these regions occur all sorts of anomalous plants.

The cold soil from which the cold ground water oozes provides for low-feeding caterpillars that hide away in the daytime on or near the ground, like the caterpillars of the fritillaries, satyrids and swamp skippers, conditions more or less comparable to those of the Transition zone, in spite of the aerial Hades three or four feet higher. It is the environment of the larvae and of the pupae that determine the occurrence of a butterfly. As for the adults, the more Hades-like the atmosphere the more they seem to like it. So it is really not so anomalous as it would appear at first sight to find Transition butterflies in the heart of the Lower Austral zone.

Two butterflies are especially characteristic of this region. One of these is a small skipper, *Amblyscirtes carolina,* found elsewhere only in similar localities in North Carolina. The other is a rather large satyrid, *Enodia creola,* known elsewhere from single examples from North Carolina, Michigan and Texas, two from Chicago, three from Opelousas, Louisiana, and four or five from near Athens, Georgia.

The case of *Enodia creola* is especially interesting. The genus *Enodia* (or *Lethe*) includes about 180 species and subspecies living in southeastern and southern Asia and western China, four fifths of them in the Himalayas, and in addition two species living in eastern North America. *Enodia creola* belongs to a small section of the genus, the subgenus *Kerrata* of Moore, in which the males are characterized by having the fore wings more or less elongate and bearing a band of shaggy androconia. The females have no distinguishing features. In addition to *creola* this group includes three species living in western China and Sikkim. All four are regarded as rare. The late Dr. William Barnes had a standing order with dealers to send him any specimens of *creola* that might come into their hands, but was never able to secure one. So far as I know, no specimen of *creola* has ever come into the hands of any dealer.

A year ago I found *creola* along the western border of the Dismal Swamp and brought back seven specimens, one male and six females, the female having been previously unknown, or at least undescribed. I doubled the number of specimens in the National Museum collection. I thought I had done rather a handsome thing. Did I get any thanks for my pains? No! It seems that, having found this species common, I should have suspended all other activities and specialized on gathering up all I could.

Last summer I brought back seventeen from near Suffolk and near Zuni. In addition to those I captured, Dr. G. W. Rawson, of Detroit, Mr. Williams, of Richmond, and W. Herbert Wagner, a high-school student of Washington, found it near Petersburg, near New Bohemia, at Zuni and near Emporia, all on the Blackwater or Meherrin Rivers. In the localized areas in which it occurs in eastern Virginia it is occasional or frequent, and in some spots near Suffolk even rather common.

Enodia creola almost always flies with *E. portlandia,* the type species of the genus *Enodia.* This also has generally been regarded as a rare insect. Two years ago I found it in abundance at Virginia Beach and secured sixty specimens, about half of which were good enough for the National Museum collection. Since then I have found it at many localities in the coastal plain, its range in Virginia being much more extensive than that of *E. creola,* which is not found east of the western border of the Dismal Swamp. I have learned that wherever I see cane (*Arundinaria gigantea*) growing in wet woods I am practically certain to find *portlandia.*

This species was described by Fabricius in 1781 from a specimen in the John Pattison Yeats collection in London. At that time many butterflies from Virginia had reached England, partly in response to advertisements inserted by Drury and others in the local papers. It is quite possible that eastern Virginia is really the type locality for *portlandia;* it seems to be more common here than anywhere else, and the name *portlandia* certainly suggests the Duchess of Portland, who at that time had a very fine collection of American butterflies. She was the wife of that Duke of Portland, prime minister of England, whose claim to a permanent place in history rests upon his affable and exquisitely courteous stupidity.

The rarity of these two species of *Enodia* in collections is due in part, at least, to a marked disinclination on the part of lepidopterists to getting their feet wet—to go sloshing through mud in more or less dense undergrowth. Many lepidopterists, I have noticed, also hesitate to face the music emanating from hordes of determined mosquitoes with a baritone element provided by huge menacing tabanids.

Both of our species of *Enodia* are unique among Virginian butterflies in being normally more or less crepuscular, flying about until it is too dark to see them. But they also fly by day, usually in the shade. Their Asiatic relatives are mainly crepuscular.

Enodia creola and *Argynnis diana* offer great temptations to speculators, both financial and intellectual. Scorning financial speculation, as I have no specimens of either, let us indulge in a bit of scientific contemplation.

If I were a botanist and *Enodia creola* were a plant I would see nothing strange in the distribution of the group to which it belongs, for several genera of plants are confined to western China and the southern Appalachians. Furthermore, if I were a botanist I would say that it is a type that once inhabited the Appalachian region—before that region got its back up, so to speak. As the mountains rose the types peculiar to that area retreated both east and west into the lowlands, so that now we find *creola* localized in the swamps of the coastal plain and also occurring at widely separated stations in the Mississippi valley.

This reasoning would make *creola* older than the mountains of Virginia and would indicate that it inhabited the mountain region before the mountains were there at all. Speaking as temporarily an incipient botanist I am inclined to believe that, on the analogy of the associated plants, this is true. But reverting to my normal status as a zoologist I refuse to commit myself.

Argynnis diana is even more interesting. It is the only truly Appalachian butterfly. It ranges from Bath County, Virginia, to Florida, east almost to tidewater, and west to Illinois and Arkansas. But it is of regular occurrence only in the mountains, where it is local and generally not common. It appears to be most numerous in Transylvania County in southern North Carolina and in more or less nearby regions. It is difficult to work out its distribution accurately, since most specimens in collections were secured from dealers who judiciously failed to provide them with locality labels.

The local distribution of this fritillary is quite anomalous—for a butterfly. On White Top Mountain I found it consorting with *Polygonia faunus smythi* in the Canadian zone. Mostly it keeps to the Transition zone, slinking through the undergrowth in steep damp valleys or on steep damp mountain sides. It is also recorded from the Upper and the Lower Austral zones.

Unlike *Enodia creola, Argynnis diana* has no close Old World relatives. What are its relatives? If you watch a male *diana* carefully you will notice that it has pretty much the same habits as a female *cybele*. In fact, it is not at all difficult to mistake a male *diana* as it zigzags through the undergrowth for a female *cybele*. You commonly detect your error just as it passes out of reach and begins to "step on the gas."

The male *cybele* is more adventurous than the female—more given to exploring open country and less to flitting through undergrowth. The female *cybele* and the male *diana* have about the same ideas on these subjects, though as a rule *diana* flies higher than *cybele*. The female *diana* is scarcely adventurous at all, keeping mainly to the woods. Frequently she comes out of the woods, flies a short distance along the roadside, then enters the woods again.

Male *dianas* frequently show on the black areas on the wings the characteristic argynnid markings, faintly traceable in deeper black. These are usually more evident in the females. Do these markings furnish any clue to *diana's* relatives?

Look between the two lowest veins on the fore wings for a black spot or mark half way between the body and the oblique bar somewhat more than half way to the outer edge of the wing. There is none. Among all our fritillaries the only ones in which the space between the two lowest veins from the body to the oblique bar has no dark mark are *cybele, leto, nokomis, nitocris, coerulescens, diana*—and *idalia,* which last is quite different. In all these the shingle-like arrangement of the scales of the fore wings in the males is interrupted over the large veins by a band of androconia In all the sexes are more or less different in color. The sexes of *coerulescens,* from the mountains of Chihuahua and southern Arizona, approach those of *diana* above, the male being heavily suffused with dark brown, which more or less obliterates the markings, and the female being dark bluish, also heavily suffused.

If *diana* is regarded as a member of this group, with which it undoubtedly belongs—the absence of the spot between the two lowest veins of the fore wings is much more important than it would appear at first sight—much of the mystery in regard to it disappears. It is true that it is an extreme form of the group in which nature seems to have tried to obliterate the normal fascies of a fritillary by an overdose of cosmetics; but the same thing has happened to a somewhat lesser extent on the upper surface, though not on the lower, of *coerulescens.*

If we can consider *diana* as most closely related to *coerulescens,* it would represent a type from the highlands of Mexico localized in the southern Appalachians, corresponding exactly to the small form of the gold-banded skipper, *Rhabdoides cellus,* found locally in the Virginia mountains.

Just what the food plant of *diana* is has never been accurately determined. Of course one suspects violets. It has been raised on violets. But if it feeds normally on violets, why has it not extended its range northward? *Cybele,* a violet feeder, which always occurs with it, ranges far northward. I can not help feeling that we have much yet to learn about this fine butterfly.

So far I have mentioned only home-loving permanent residents of Virginia. In addition to these permanent inhabitants, the justly famed hospitality of the state attracts in the summer many rhopalocerous as well as human tourists. Chief among these summer visitors is the rather large clear yellow pierid, *Phoebis eubule,* known in parts of the South as the "traveling butterfly."

So far as I have been able to ascertain, this insect does not overwinter in Virginia, being killed off in all stages in the winter. It appears in early summer coming up the coast and up Chesapeake Bay, and also filtering in through the mountains in the southwest from the Mississippi valley. By the end of the summer it has become common, or at least frequent, over the greater part of the state, being especially numerous along the sea coast and in the west.

In certain regions it is usually observed dashing along in one definite direction with a determined and purposeful air. In other regions it seems to fly indiscriminately in any direction. The same thing has been noticed in various other places in the South. It seems to be imbued with a frantic desire to get away from some regions as fast as possible, something after the fashion of a cockroach on a hot stove In other regions it just dashes wildly about. You see it doing this at Big Meadows on the Skyline Drive in late summer. If one is entomologically inclined and wishes to lose a few pounds I can not imagine a better or more effective method of accomplishing this end than by trying to catch this species here.

Another summer visitor to Virginia is the Gulf fritillary, *Dione vanillae.* This comes up the coast region and is sometimes common about Norfolk. Still another is *Ascia monuste,* the southern cabbage white, also known only from the coastal region.

The salt marshes along our eastern coast support two species of butterflies found nowhere else. Both are skippers, one *Panoquina panoquin,* brown, the other, *Poanes aaroni,* chiefly bright yellow. The little brown chap is common or abundant in all the salt marshes, and especially numerous on the Eastern Shore and about Lynnhaven. I have found it as far north as Mathews County. The yellow one so far has eluded me, but Mr. Frank Morton Jones has recorded it from Chincoteague Island and has sent me records from other places.

In order to catch these salt marsh skippers you must first locate patches of flowers—sea-lavender or sea-oxeye. If there are any of these skippers anywhere about they will be found on these flowers. It is almost hopeless to try to catch them over a broad amorphous expanse of salt marsh without flowers, for you do not see them until they suddenly jump up and almost instantly seem to dematerialize into thin air. I may add that unless you are still addicted to that joyful amusement of all children, paddling about in muddy water, you will search for these skippers only when the tide is out.

Many of the butterflies of Virginia have only a single brood a year. This brood may appear only in early spring, as in the case of the little brown hairstreak *Incisalia augustinus, Pyrgus centaureae, Hesperia metea, Atrytonopsis hianna,* etc.; it may appear in early summer, as with *Euphydryas phaëton;* it may appear in midsummer, as with *Strymon titus mopsus*; or it may not appear until the end of the season, as in the case of *Hesperia leonardus.*

The large fritillaries—*Argynnis diana, A. cybele* and *A. aphrodite*—are supposed all to be single brooded, but the single brood emerges from early summer until almost the end of the season. The same is the case with *Cercyonis alope,* which flies from about the first of July onward; but in this species the males are relatively short lived and disappear while the females are still numerous.

One-brooded butterflies are nice little boys—and girls—to deal with. They mostly stick closely at home. You don't get zoogeographical jitters in trying to explain their basic distribution. It is true that they are frequently so localized that they are difficult to find, but when you do find them they are almost always common in their home territory. The species that fly only in very early spring are sometimes rather rare in collections, largely because of the disinclination of many lepidopterists to face the chilly breezes of that season.

Most of the one-brooded butterflies appear all at once and fly for only three or four weeks. They are nice conservative models for other butterflies to follow. They are very satisfactory to deal with, for in them variation is, as a rule, reduced to a minimum. The fritillaries have a somewhat disconcerting way of varying from early summer, when they first appear, to autumn. These variations have been studied only in the case of *Argynnis cybele.*

A number of butterflies have one full brood in spring or early summer and a partial brood, or broods, sometimes represented by very few individuals, in summer. This is true especially of certain skippers, as for instance the silver-spotted skipper and a number of its relatives, and of some satyrids, as *Satyrodes eurydice.* In these species the caterpillars from the eggs laid by the adults of the first brood form pupae, most of which remain as pupae until the following spring; but from a few the butterflies emerge later in the season. In most of our swallowtails and not infrequently in our pierids some of the pupae of each brood remain dormant until the following spring, the second brood being therefore not quite complete. In butterflies with a partial second brood the individuals of this brood usually resemble those of the first, though they may differ more or less from them.

Many Virginian butterflies have two broods. In one case, that of the little orange-tip, *Anthocharis genutia,* as it occurs at Blacksburg, the second brood immediately follows the first and the species entirely disappears in early summer. In most cases the first brood appears in spring and the second in summer. This is the case with all the swallowtails except *Papilio marcellus,* which has three or more broods, with all the angle-wings except *Polygonia faunus smythi,* which is single-brooded, and with various other species.

No butterfly could be expected to overlook an opportunity like this for disconcerting the lepidopterist. So we find that in two-brooded species the individuals of the two broods almost invariably differ more or less markedly, those of the second brood being usually larger, darker and with shorter wings than those of the first. It would not be so bad if rhopalocerous irresponsibility stopped here. But it goes further. The angle-wings, which live over winter as adults, all emerge in autumn under essentially similar conditions. The individuals one sees in the spring, therefore, are usually pretty much all alike. In the case of the swallowtails, however, the emergence of the spring brood from the overwintering pupae covers a considerable period of time and a wide range of conditions.

In most of the species the earliest individuals of the spring brood are much smaller than those that appear later, and sometimes differ rather widely from them. Thus in certain years the earliest examples of the blue swallowtail or "silk-butterfly," *Papilio philenor,* as found at Leesburg and probably elsewhere, lack the tails, and the metallic green on the under side of the hind wings is restricted in extent. These tail-less blue swallowtails scarcely differ from the form called *acauda* from the hot lands of Mexico, and if their origin were unknown would certainly be referred to it. Other individuals in early spring have the hair on the body so long that they look moldy, and also have a row of conspicuous white spots on the upper surface of the wings. These may be referred to the form *hirsuta,* the prevailing form in northern California. The children of these, and indeed their own brothers and sisters that emerge later, are much larger—the common type of eastern blue swallowtail.

The very small yellow swallowtails, *Papilio glaucus,* that you see in the woods in early spring are quite different from those you see in late spring and in summer. They have a pre-nasal tuft of long whiskers on the frons and long hair on the body, and are colored like the form called *canadensis,* which flies in the far north. You will find that *canadensis* is given as the northern subspecies of the typical *glaucus* of the South. But if you go strictly on the basis of specimens and keys you can not separate early spring individuals taken in Virginia in certain years from *canadensis.* In the South only the males of this form occur, so far as is known. The larger females, which emerge later, are more like the summer form. If you go on the basis of specimens and keys only, disregarding locality labels, you will inevitably reach the conclusion that *canadensis* occurs in both sexes in the far north where the species is single brooded, but in Virginia is found only in early spring and in the male sex only. If *canadensis* is to be regarded as a valid subspecies it must be considered as parthenogenetic in the South, where only one sex occurs. As I am not as yet converted to the idea of any parthenogenetic animal occurring in the male sex only, I prefer to regard *canadensis* as a variety rather than as a subspecies of *glaucus.*

It may be mentioned that in the case of two-brooded butterflies the habits of the individuals of the two broods are usually more or less different. In the swallowtails the individuals of the spring brood keep to the woods, or to the borders of the woods, and are very active, as if their small size imbued them with an inferiority complex urging them to cover as much territory as possible. The larger individuals of the summer brood are lazier and more indolent, and bolder, ranging far over open country. In the case of the angle-wings, however, it is the long-winged light-colored form that wanders, the short-winged dark summer individuals staying pretty much at home.

The numerous butterflies with three or four broods offer additional difficulties. For usually the spring brood is more or less localized, the successive summer broods spreading over wider and wider territory. As in the case of two-brooded species, the first brood may have two or more very different forms, as is well seen in the common blue, *Lycaenopsis argiolus pseudargiolus,* and the checkered white, *Pieris protodice.* The worst feature of the situation is that so many of the butterflies with several broods are skippers, and skippers are so small that they often pass unnoticed unless they are rather numerous.

There are various skippers in Virginia that are recorded only in the summer or autumn. Whether these come in from the South each year, or whether they are permanent inhabitants overlooked earlier in the season on account of their small size, scarcity and general inconspicuousness, has not been determined.

Two of the several-brooded Virginia butterflies have a very wide distribution, being found practically all over the northern hemisphere. These are the common blue, *Lycaenopsis argiolus,* and the small copper, *Lycaena phlaeas*; the latter ranges as far north as land extends. In both of these the early spring individuals resemble those from further north, where there is only a single brood, though not necessarily those from the most northerly portions of their ranges.

The really distressing thing about these butterflies with several broods you do not notice until the end of the season in late September or October, and ordinarily not then unless the season is rather dry. If conditions happen to be just right the wretched things again appear in the spring form, though without any infuscation. Fortunately most lepidopterists have become tired of collecting butterflies when October comes around, so none of these late forms have received names.

In the winter they go still further. In the case of *Colias eurytheme* the upper surface becomes very light, the under side dark green; the hind wings become elongated, and the brown circle in the center of the under side is extended outward in a long triangle. In this camouflage individuals look for all the world like some strange Arctic species. All three forms of *eurytheme* are modified in the same way. The white females are particularly puzzling, as they have a way of becoming greenish above.

The common little tessellated skipper, *Pyrgus communis,* in the winter loses all the brownish on the under side of the hind wings, becoming black and white. You would scarcely guess what it was if you did not know it could not be anything else.

One of the interesting things in regard to Virginia butterflies is the way the same species differs in size in different areas. For instance, *Cercyonis alope* is small and dark in the mountains—the form *maritima.* In the piedmont it is larger and not so dark—the form *alope.* Near the sea in southern Princess Anne County it becomes very large—the form *pegala.* It is easy to remember the distribution of one of these forms. Just bear in mind that when it comes to *Cercyonis alope* in Virginia *maritima* means farthest from the sea. Perhaps I should add that in the western mountain meadows this butterfly frequently suffers from a sort of systematic lunacy. The yellow on the fore wings may be replaced by white, or it may become very dark, and all sorts of inexplicable variations occur.

A number of other butterflies are small in the mountains, becoming larger as you approach the sea. But just the reverse is the case with the common blue. In the mountains you find extraordinarily large individuals, while the smallest are those from near the sea coast.

In studying the butterflies of any region there is one thing you have to look out for. In many species the relative proportion of the sexes varies widely in different localities The males as a rule wander more widely than the females. In the swallowtails, for instance, the females generally tend to keep near the woods, while the males scatter all about. On the muddy banks of streams you often see many butterflies sucking up moisture. These are usually all males It is very seldom that you find bibulous ladies among our butterflies.

Some species, of course, are always ready to upset the nicest generalizations. Thus the pretty little skipper, *Poanes zabulon,* is unorthodox in that the males are the ones that stay at home, being found chiefly along the sides of streams through the woods. The females prefer the more abundant life, wandering widely over open fields where the males seldom or never venture.

There is much of interest yet to be learned about our butterflies if you regard them as living things and not as nature's artistic triumphs to be impaled on pins with unnaturally extended wings.

To me, at least, it is much more satisfying to wave an insect net than a golf stick or a tennis racquet. I get quite as much exercise in the long run. Then there is always the gamble; you never can tell when you will get something really worth while. And when you have captured something really worth while, why, there it is in your collection. That is why you hear much about fish stories, but nothing about butterfly stories.

INAPPARENT VIRUS DISEASES[1]

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WE naturally think of virus diseases as exemplified by those we have heard most about. The epidemic of encephalitis, which struck St. Louis in the late summer of 1933, was certainly not neglected by the newspapers. The pandemic of influenza in 1918 was unforgetable. Infantile paralysis is a virus scourge which, we have reason to believe, is more devastating in the United States than in other parts of the world. There are many others—yellow fever, smallpox, common cold and so on. These virus diseases compel us to do something through fear of death or disfigurement, but the good resolutions made in time of epidemic soon pass away and research is sadly handicapped by lack of funds.

Another group of virus diseases affects domestic animals. Hog cholera, rinderpest and foot and mouth disease are typical. The motive to overcome them is to save dollars, and they were brought under control promptly.

No class of vertebrates escapes. Among the invertebrates many viruses operate, especially in insects.

In plants, as in domestic animals, the economic loss stimulates research so that much attention is given to the virus diseases of tobacco, potatoes and sugar cane. Over a thousand species and varieties of plants are known to be subject to these diseases,[2] and the number steadily increases.

Even the lowly bacteria are not exempt. They are destroyed by special viruses called bacteriophages.

Viruses constitute a hazard for all classes of living things from the highest to the lowest. Fortunately some species, perhaps genera, and possibly orders are not so afflicted, and for any given susceptible species the mortality is seldom 100 per cent. and the chances for infection may be small; otherwise, life would be extinguished wholesale.

It is interesting to note that virus diseases grade from extremely dangerous to seemingly harmless conditions. Persons bitten by mad dogs, who are untreated and contract rabies, invariably die. But this 100 per cent. mortality is extremely rare in human virus diseases, though it is the rule in some lower forms. In yellow fever, smallpox, encephalitis and many severe virus diseases some of the afflicted individuals usually recover.

There are other virus diseases which are seldom if ever fatal in uncomplicated cases, as for instance, herpes, common colds and warts.

A true conception of the action of any virus involves a consideration of the mild cases of disease which it provokes as well as of the serious ones. Both are equally part of the picture. Take infantile paralysis. In times of epidemic only a very small percentage of the population is affected, almost wholly children and very rarely mature individuals. The explanation is that in cities many children and at least 80 per cent. of adults have had mild, undetected attacks which produce immunity. In rural districts the percentage is a little lower. The precise number can not be calculated, owing to the expense of making immunity tests, but perhaps only one in five or ten thousand cases of poliomyelitis is sufficiently severe to be recognized as infantile paralysis. Certainly in an overwhelming majority of instances the disease passes unnoticed. Why a few cases should flare up with such tragic results is an enticing problem.

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[1] Aided by an appropriation from a grant by the Rockefeller Foundation to Washington University for research in science.

[2] M. T. Cook, SCIENTIFIC MONTHLY, Feb., 1937, 174–177.

Recent investigations show that other dreaded virus diseases are ordinarily unrecognized and only exceptionally produce dangerous infections, notably yellow fever among natives hundreds of miles inland from the West coast of Africa, where formerly it was thought to be altogether absent.

Very significant is the fact that some viruses seem invariably to act without exhibiting any clinical symptoms at all. The persons or animals involved remain entirely healthy. These are the *inapparent viruses.*

We may well ask: How can viruses, which produce no noticeable symptoms, be detected?

Until so many were encountered that investigators looked purposefully for them, they were discovered only by accident. Thus, Rivers and Tillett[3] injected blood from cases of chickenpox into the testicles of rabbits in an attempt to isolate a virus. After a suitable interval, they removed the testicles, ground them up in physiological saline and injected the material into the testicles of a second rabbit. Several passages from animal to animal were made in this way on the theory that any virus present in the original blood and not showing on the first transfer would increase in amount or virulence. And a virus did appear capable of producing distinctive lesions and nuclear inclusions in the skin and cornea as well as in the rabbit testicles. But Rivers and Tillett proved that the virus was not that of chickenpox. Instead, it was an inapparent virus of rabbits strengthened by passage.

Consequently, in attempts to pass pathogenic viruses, great care is now taken to make sure that an inapparent virus is not awakened from a condition approaching dormancy in symptomless animals which look normal.

Very tragic consequences have brought to light another inapparent virus. Some years ago the King of Greece was bitten by a pet monkey and died in a mysterious way. One of my assistants, Dr. B., while working in New York was also bitten by an apparently healthy *Macacus rhesus* monkey. He died of paralysis. A hitherto unknown virus was isolated from his spinal cord which is easily maintained in rabbits which it kills.[3a]

Again, by chance, Jackson[4] observed bodies in the submaxillary glands of guinea pigs which she thought were protozoa. It was found, however, by Cole and Kuttner[5] that they were duct cells modified by virus action. Discovery of this "salivary virus" pointed the way to the recognition of a whole series of inapparent viruses. Cells similarly altered in the salivary glands of mice, rats and small Chinese rodents, called "Hamsters," served as clues. In addition the salivary glands of some human infants, *Cebus fatuellus* monkeys and moles show comparable alterations strongly suggestive of virus action, which action has, however, not been demonstrated experimentally.

A conspicuous feature of the modification is the formation of inclusions within the nuclei. Fig. 1 illustrates the inclusion laden cells in two sections of the submaxillary gland of *Cebus fatuellus.* In the one on the right a very much enlarged duct cell is shown. It is binucleated. The upper nucleus is cut about through the center and exhibits a centrally placed nuclear inclusion, which appears dark gray in the photograph but which, in the original preparation, was stained pink with eosin. Since eosin is classed as an acid dye, the inclusion is said to be "acidophilic." It is seen to be surrounded by a clear halo, and most of the basophilic chromatin (in black) is displaced toward the nuclear membrane. Only a slice from the side of the lower nucleus is included in the section. The limits of the cytoplasm are easily distinguished and within it certain cytoplasmic inclusions in the form of roughly spherical dark gray masses of unequal size.

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[3] T. H. Rivers and W. S. Tillett, *Jour. Exp. Med.*, 38: 673–690, 1923.

[3a] A. B. Sabin and A. M. Wright, *Jour. Exp. Med.*, 59, 115–136, 1934.

[4] L. J. Jackson, *Jour. Infect. Dis.*, 26: 347–350, 1920.

[5] R. Cole and A. G. Kuttner, *Jour. Exp. Med.*, 44: 855–873, 1926.

In the section on the left, a single-nucleated, enlarged duct cell is seen. Its nucleus is hypertrophied and exhibits a similar centrally located acidophilic nuclear inclusion surrounded by a clear halo, with chromatin and nucleolus tending to marginate on the nuclear membrane. A few hazy cytoplasmic inclusions are visible.

It is to be noted that in both single cells are affected and the neighboring duct cells show no signs of injury.

The problem is enlarged by the discovery of nuclear inclusions, unassociated with recognizable disease in various other parts of the body and particularly in the kidneys. Indeed, it is difficult to mention any species of laboratory animal, whose tissues have been repeatedly examined, which does not occasionally show nuclear inclusions in some tissue or other, even though it is only in a very small percentage of individuals. The probability that such nuclear inclusions are expressions of virus action decreases in proportion as their properties depart, either from those in the guinea pig's submaxillary or from those caused by the hepetic virus which can be regarded as standard types.

Whether a given species, subject to the occurrence of nuclear inclusions in several organs, harbors more than one inapparent virus remains to be determined. After the salivary glands, the kidneys most commonly exhibit the inclusions, sometimes in species (*Macacus rhesus*) which do not show them in the salivary glands, while there are instances of species (moles and *Cebus fatuellus*) which have them in the salivary glands and not in the kidneys. Only successful attempts to pass the hypothetical viruses will ultimately settle the question as to their number and relations in each species.

One difficulty is that all viruses of this group, thus far isolated, are species specific. That is to say, they will take only in animals of the same species so young that their mild natural susceptibility has not been converted into resistance by naturally acquired inapparent infections by the virus. The difficulty of working with humans, *Cebus fatuellus* monkeys, moles and hamsters is clear.

How long do these inapparent viruses persist in animals which show no signs of disease?

The age of guinea pigs naturally invaded by the salivary virus is about one month. That adult guinea pigs, which possess nuclear inclusions, contain virus is proved by intracerebral inoculation of animals less than one month old.

Nobody appears to have taken the trouble to purposefully infect the submaxillaries of a series of young guinea pigs, to keep them for years and to test for the persistence of virus. It is likely, however, that some adult guinea pigs, from which active virus has been obtained, were rather more than a year old. A conservative estimate, therefore, places the possible length of persistence of guinea pig salivary virus at one year. It is unlikely that persistence merely results from reinfections, because in adult guinea pigs, and other animals, the inclusion-laden cells have attained a maximum development. Inclusions of variable size suggestive of active formation are conspicuous by their absence.

In *Cebus fatuellus* monkeys salivary gland inclusions have only been reported in adults. The age of these adults was estimated at three years.[6] The time of invasion is problematical; but, if these inclusions were produced by a virus operating like all other salivary viruses do in extreme youth, the persistence of virus may have been for, say, two years.

By what mechanisms do these inapparent viruses persist when other pathogenic nuclear inclusion forming viruses disappear?

It is logical to assume that the persistence is associated with the retention of nuclear inclusion containing cells; whereas such cells in herpes or smallpox go on to complete necrosis, are removed and the respective viruses can no longer be found.

When the inclusions reach a stage of maximum development, at which they may remain for months, the respective cells are apparently dead. Evidence for death is not all that might be desired. It is not feasible to test their oxygen consumption, if any. But Pearson[7] has found that they have lost all mitochondria, which certainly indicates death. The same investigator observed that, when transplants of submaxillaries were made into the peritoneal cavity, the inclusion containing cells remained without change in striking contrast to the neighboring epithelial cells which promptly underwent autolysis. Perhaps the inclusion-laden cells did not change because they were already dead. They may bear, not a charmed life, but a charmed death!

A few cells in this curious state are cast off into the duct and eliminated in the salivary secretion. This may be the means of natural spread of the virus. But many cells remain for long periods. The death changes in them are halted, and they are not attacked by leucocytes. Their neighbors may be affected but often appear in every respect normal and uninfluenced by their presence.

It looks as if we are dealing with attachment of potentially active virus to dead cells, despite the fact that these duct cells are washed by large volumes of water which pass through the epithelial walls of the ducts to dilute and carry away the secretion of the acinous cells.

The situation in the kidney is equally interesting. We have alluded to the small percentage of adult *Macacus rhesus* and of rats which exhibits greatly enlarged renal cells charged with inclusions both nuclear and cytoplasmic indistinguishable from those in the salivary glands. Such cells are illustrated in Fig. 2. Note the centrally placed inclusions surrounded by clear halos. In these particular sections, the cytoplasmic inclusions are less marked. The neighboring cells exhibit no signs whatever of nuclear inclusion formation. Here again the nuclear inclusions are at a maximum, the cells look dead, a few are desquamated and may pass out in the urine as infective material, but some remain and are immune to the usual forces of disintegration. In the convoluted tubules, where they ordinarily occur, they are, as in the salivary glands, washed in water, though the water passes inward, in the process of resorption and concentration of urine, not outward.

Are any of these inapparent viruses ever dangerous?

When monkeys are given fairly large doses of viosterol the number of them which show the above-mentioned renal nuclear inclusions seems to be increased. In 125 untreated monkeys they were observed in 21, or in 16.8 per cent. In 16 treated monkeys, on the other hand, they were detected in 12, or in 75 per cent., and they were often accompanied by signs of injury. Perhaps the dosage kindled an inapparent virus, but proof is lacking.

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[6] E. V. Cowdry and Gordon H. Scott, *Am. Jour. Path.*, 11: 647–657, 1935a; *ibid.*, 11: 659–668, 1935b; *Arch. Path.*, 22: 1–23, 1936.

[7] E. F. Pearson, *Am. Jour. Path.*, 6: 261–274, 1930.

Some cases of meningitis are caused by a virus identical with an inapparent virus discovered in seemingly healthy mice by Findlay, Alcock and Stern.[8]

In the lungs of 18 out of 40 cases of whooping cough McCordock and Smith[9] have found nuclear inclusions resembling those of the salivary glands. They were absent in all but 2 of 90 routine autopsies. Perhaps whooping cough is caused by an awakened hitherto inapparent salivary gland virus acting in cooperation with the Bordet-Genou bacillus or the *Bacillus bronchisepticus*.

Several instances are on record of two pathogenic viruses operating in a single individual at the same time. When this happens, infection by one of them may be unusually severe. Thus, in a child, not yet recovered from the mumps, rabies virus spread to the central nervous system from a small bite on a finger with unprecedented speed and so irresistibly that Pasteur treatment was unavailing, whereas others not having mumps and much more extensively bitten by the same dog, treated in the same way, all survived. (Dr. D. L. Harris, personal communication.)

The converse also holds but perhaps less frequently. One virus may decrease the severity of attack by another. Monkeys suffering from experimental inoculations of dog distemper virus were more resistant to poliomyelitis (infantile paralysis) virus than normal monkeys. The usual poliomyelitis mortality was indeed reduced for them from 100 to 33 per cent.[10]

It is possible, therefore, that inapparent viruses, which probably lurk in bodies of some of us and of many animals unnoticed, may similarly gear up or reduce the virulence of easily recognized, superimposed pathogenic viruses. If this is found to actually happen it may contribute one factor in the as yet unexplained difference in individual susceptibility to virus diseases. It may explain, for instance, why a few persons die or are maimed for life by an attack of infantile paralysis which the vast majority survive without even showing any symptoms of the disease.

What is the probable extent of distribution of inapparent viruses?

Obviously they are not limited to the particular group of salivary viruses. Other nuclear inclusions are encountered by chance in animals which appear to be quite healthy. The inclusions in the livers of dogs are a case in point. They resemble closely inclusions found by Green and his associates[11] in foxes. That inapparent viruses occur, which do not even lead to nuclear inclusion formation, is evident. Virus III of rabbits exists without forming inclusions until its virulence is stepped up, or until its amount is increased.

Viruses that form nuclear inclusions are only a small fraction of the total. Many pathogenic viruses produce cytoplasmic inclusions and others no inclusions at all. It is likely that cytoplasmic inclusions will also serve as clues to inapparent viruses and that still other inapparent viruses, which produce no inclusions of either sort and few if any symptoms, will eventually be encountered. At present we must entertain the possibility, even probability, of their presence in all species of mammals. It is premature to speak about other vertebrates, the tissues of which we examine only rarely.

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[8] G. M. Findlay, N. S. Alcock and Ruby O. Stern, *Lancet*, pp. 650–654, March 21, 1936.

[9] H. A. McCordock and Margaret G. Smith, *Am. Jour. Dis. Child.*, 47: 771–779, 1934.

[10] G. Dalldorf, M. Douglass and H. E. Robinson, *Science*, 85: 184, 1937.

[11] R. G. Green, M. S. Kalter, J. E. Schillinger and K. B. Hanson, *Am. Jour. Hyg.*, 18: 462–481, 1933.

From numerous references in the literature, it is clear that these viruses are widely distributed geographically. But a world survey is very much needed, particularly of the salivary viruses, which will include districts remote from the lines of travel. Are such inapparent viruses found in the animal inhabitants of the tropical jungles along the Amazon and in the forests along the MacKenzie River in the far north? Expeditions, financed by museums, might well provide material from the animals collected.

We know that the mouse virus exists on both sides of the Atlantic and the rat virus on both sides of the Pacific. Specimens from the salivary glands of children in remote parts of the world contain nuclear inclusions, like those from St. Louis children, and so on. Members of a given species, wherever they may be, are generally involved though perhaps in a small percentage of individuals. But there are exceptions. Certain colonies of guinea pigs, for instance, are devoid of inclusions. It may be that their ancestors were removed from exposure to infection in their early youth.

Is there any way of estimating the age of inapparent viruses?

It is generally assumed that a virus, which is found wherever animals susceptible to it occur throughout the world, has been active in the particular species affected for a considerable time, in other words, that the spread has been time-consuming. This argument, however, must be partly discounted for animals which move actively from place to place and which may quickly spread the virus they carry over wide areas. Humans and domestic animals are the greatest travelers.

Conversely, a virus, active in a restricted geographic area, despite the fact that the members of a susceptible species are widely distributed in many parts of the world, is often regarded as of more recent origin particularly if it is pathogenic (*i.e.*, poorly adapted to its host).

The myxomatosis virus of rabbits and the encephalomyelitis virus of horses (which differs from the Borna virus) are instructive in this connection. Findlay[12] has pointed out that both afflict only rabbits and horses of the New World, although rabbits and horses elsewhere are equally susceptible. Since these two animal species have entered the Americas in historic times, he suggests that the myxomatosis and encephalomyelitis viruses are recent invaders.

Reckoned on the basis of extent of distribution, the salivary gland viruses have been operating for many years. The degree of adaptation of each to a single species of host, and to a definite tissue in that host, was probably achieved slowly. Whether the time is to be measured in hundreds or in thousands of years is pure speculation. To consider evidence on the antiquity of parasites is a natural step in trying to date the viruses which may themselves be parasites.

Metcalf[13] refers to opalinid protozoa of the genus *Zelleriella* as of "comparatively modern" origin, probably in the early or middle tertiary. This genus made its début in Leptodactylid frogs of South America sometime between 18 and 54 million years ago, if we follow Gregory[14] in his estimation of geological time. The frogs, with this parasite, immigrated into Central and North America in the Pliocene, say about 7,000,000 B.C. At present frogs of this kind are only found in the Americas and on the other side of the Pacific, in Australia. In both locations they carry Zelleriellas in their intestines, which may even be identical as to species. Metcalf suggests that the frogs with these parasitic protozoa, which by now are rather well adapted to them, migrated from South America to Australia by a land bridge long since sunk beneath the waves.

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[12] G. M. Findlay and others, *op. cit.*

[13] M. M. Metcalf, *Am. Naturalist*, 57: 385–411, 1923.

[14] W. K. Gregory, "Cowdry's Human Biology," pp. 53–90. New York: Paul B. Hoeber, Inc., 1930.

"Are some viruses equally modern?" is a question that we may never be able to answer, but it is possible. However this may be, adaptation of the salivary viruses is not yet complete. When, in a natural infection, the virus first invades the salivary glands of guinea pigs, there is a slight tissue reaction indicative of injury. But it has become so acclimatized to the salivary glands that, in this situation, it never kills, and clinical symptoms have never been reported though they may occur. When, however, the virus is introduced into the brains of young guinea pigs death ensues.

We wonder whether nature holds, for our discovery some day, viruses which by the same slow, inexorable adaptation have gone farther and have attained complete adjustment to their hosts. Perhaps such complete adaptation would be inconsistent with continued propagation of virus. All known viruses cause the death and disintegration of some host cells. If the cells were not injured sufficiently to cause them to go to pieces, virus might remain locked up in them and fail to reproduce itself by spread to other cells, invasion and multiplication in them.

With some other forms of life, adaptation leads to an association which is mutually beneficial. There is no reason to think that viruses ever enter into this sort of partnership with their hosts, but it is conceivable that they do so.

What are the viruses?

The main and cogent reason why most people believe that the viruses, both inapparent and pathogenic, are living organisms is that they, like some bacteria and protozoa, are transmissible from host to host and that in each host they increase in number or multiply. That the viruses are particulate has been demonstrated. The particles of most of them are from 0.1 to 0.01 micron in diameter—that is to say, the diameter of virus particles is so small that from 250,000 to 2,500,000 of them placed side by side in series would extend a distance of only one inch.

It has been repeatedly claimed that viruses constitute hitherto unrecognized forms of life of evolutionary significance which are transitional stages from nonliving to living material. This seductive idea is unwarranted; for, since they prey upon living cells and can only multiply, or increase in number, in association with living cells, they are dependent on them and can not be looked upon as having antedated them in the evolution of living beings.

Green[15] sees in the adaptation of free living forms to a parasitic existence clues to the nature of viruses. Tapeworms in the intestinal tract, for instance, have food supplied to them by their hosts and lose the ability to seek and capture it for themselves. They do not need to see, hear, smell or equilibrate, so that sense organs are lost or are not developed. A digestive system is unnecessary. Except for ability to hold tight and multiply there is a reduction of parts. He regards the viruses as organisms (sporozoa), which, in adaptation to a sheltered intracellular existence, have likewise lost parts no longer necessary. In fact, he thinks that they have lost cytoplasm and nucleus, indeed everything except the fundamental structural

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[15] R. G. Green, *Science*, 82: 443–445, 1935.

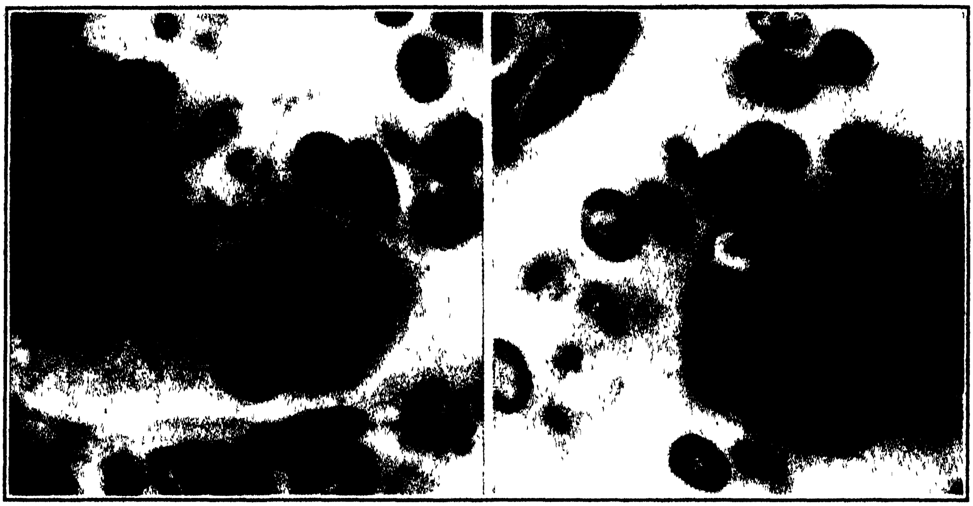

FIG 1. PHOTOMICROGRAPHS OF SECTIONS OF SUBMAXILLARY GLANDS OF MONKEY (*Cebus fatuellus*) ON RIGHT IS REPRESENTED A MUCH ENLARGED BINUCLEATED DUCT CELL. ONLY THE UPPER OF THE TWO NUCLEI IS CUT THROUGH ITS GREATEST DIAMETER THIS SHOWS A LARGE, DENSE, DEEPLY STAINED, OVAL NUCLEAR INCLUSION SURROUNDED BY A CLEAR HALO ON THE LEFT IS ANOTHER ENLARGED DUCT CELL POSSESSED OF A SINGLE NUCLEUS CONTAINING A NUCLEAR INCLUSION SURROUNDED BY A HALO

organization necessary for multiplication When cells containing them are ruptured, they escape as living things reduced to the smallest possible size capable of persistence under certain conditions, but not of multiplication unless they gain entry into cells which afford precisely the right kind of nourishment.

This is an attractive conception, extremely difficult to prove or disprove The anaplasma, found in red blood cells and associated with devastating diseases of cattle, as the name implies, may be viruses without cytoplasm,[16] having lost it in the process of adaptation to intracellular life; but they afford only feeble support to the theory.

Several etiological agents, formerly thought to be viruses, have been found to be organisms which flourish within cells and are called Rickettsias after Howard Taylor Ricketts, who died from infection by one of them These Rickettsias are almost at the limit of microscopic visibility, so that some reduction in size may have been effected owing to dependence upon the host cells and loss of unrequired parts.

If the original virus organisms were lowly plants (bacteria or moulds) is it likely this reduction of parts would have occurred? We can not answer, but we can point to the symbionts of the arachnids and especially of the ticks[17] These are very perfectly adapted to their arachnid hosts They even inhabit the eggs and are transmitted hereditarily from generation to generation. This has probably been going on for a long time. Yet they are fairly robust microorganisms, easily visible with oil immersion lenses, and none of them have, as far as we can ascertain, been reduced to tiny clumps of reproductive molecules.

The similarity, recently emphasized by Gowen and Price,[18] between viruses and

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[16] E. V. Cowdry and C. W. Rees, *Am. Jour Hyg.*, 21: 94–100, 1935.

[17] E. V. Cowdry, *Jour. Exp. Med.*, 41: 817–830, 1925.

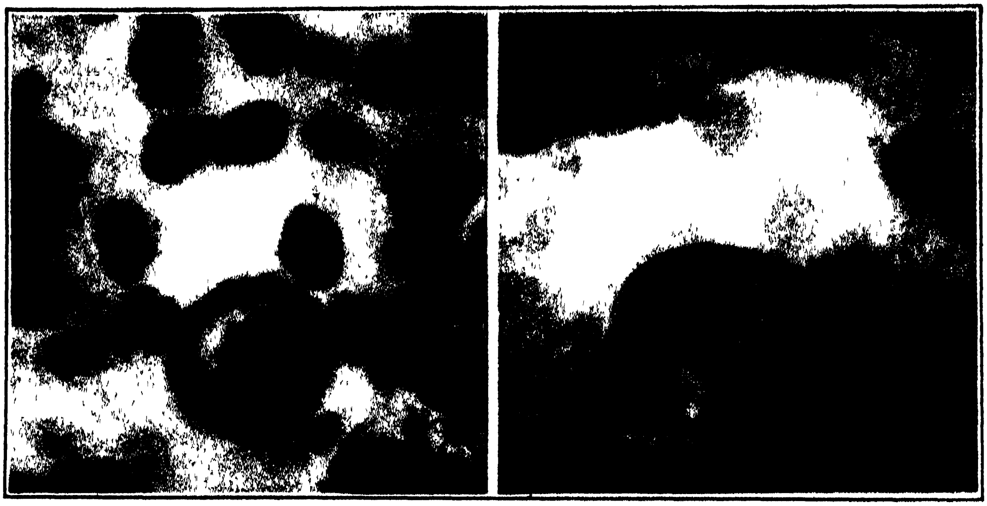

FIG. 2. PHOTOMICROGRAPHS OF SECTIONS OF KIDNEYS OF MONKEYS (*Macacus rhesus*). IN BOTH SINGLE HYPERTROPHIED CELLS ARE SHOWN WHICH EXHIBIT NUCLEAR INCLUSIONS LIMITED BY CLEAR HALOS.

genes is not inconsistent with Green's theory. They are of about the same size, incapable of multiplication outside living cells and produce variegation or mottling in plants. Both mutate under natural conditions, and the resulting new forms perpetuate themselves Both are inactivated by x-ray and ultra-violet light.

Viruses, however, differ from genes in movement from cell to cell and ability to cause disease in healthy plants To assume that viruses are detached genes is unwise for many reasons. To do so is obviously inconsistent with the unsupported but popular idea, already mentioned, that viruses constitute steps between non-living materials and the earliest, most primitive organisms. Since the genes develop within cells they can not have been formed before the said cells originated. Consequently, in this view also, viruses, as liberated genes, must have followed, not preceded, the evolution of cells.

The purification and crystallization of plant mosaic viruses has been taken as evidence that these particular viruses, at least, are non-living. Vinson was the pioneer in this field.[19] In an editorial the *Journal* of the American Medical Association (99· 656, 1934) refers to his work and says that successful crystallization of mosaic virus " . . . may be regarded by future medical historians as one of the most important advances in infectious theory since the work of Lister and Pasteur." The purification has been confirmed and greatly extended by Stanley.[20] The same journal has emphasized, in another editorial, the importance of Stanley's studies.

It is true that when removed from the cells in the process of purification the one feature which stamps mosaic viruses as living, namely, ability to multiply, is lost. They may be then in fact inanimate, as ability to withstand crystallization, solution and recrystallization seems to show.

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[18] J. W. Gowen and W. C. Price, *Science*, 84: 536–537, Dec. 11, 1936.

[19] C. G. Vinson and A W. Petre, *Contrib. from Boyce Thompson Institute*, 3: 131–145, 1931.

[20] W. M. Stanley, *Science*, 81: 644–645, 1935.

In susceptible cells, however, it may be a different story, for in them favorable conditions for nutrition and multiplication are afforded, as they are for a great many other viruses, which appear equally dead when separated from cells.

Viruses constitute a large and heterogeneous group. That some will be found to be tiny microorganisms is likely Others may be organisms, reduced in size in adaptation by loss of unrequired parts, as Green suggests. Still others may not be organismal at all It is possible that these are chemical substances occasionally originating in consequence of vital activities, which, when once formed, continue to produce more of themselves, if they are given suitable living material on which they can work, as autocatalytic enzymes.

This mechanism of virus formation, if it ever operates, does so only on extremely rare occasions. Viruses change, but no virus has yet been found to originate *de novo* from non-viral material From an ancestral pox virus many different pox viruses may have developed A virus originating in one animal may spread to many others of the same and different species.

The chance of the formation of viruses at rare intervals may be a kind of hazard, or risk which nature runs as chemical and physical forces are harnessed in the evolution of life on earth. Human beings are subject to a greater variety of virus diseases than are any other animals. Many viruses spread to us from lower forms, but some may have originated in our remote ancestors Consider the female sex hormone, theelin Here a risk is balanced against a gain. The production of this substance has facilitated the differentiation of higher forms and of man The hazard which nature has run to achieve this result is that theelin is a dangerous substance closely related chemically, and also in its action, both to an essential vitamin (D) and to substances that can cause cancer The *Journal* of the American Medical Association has an editorial on cancer as a virus disease Medical science is advancing, and unexpected light is being shed on many problems in which the viruses occupy a central place.

A REMNANT OF VIRGIN FOREST IN CENTRAL NEW ENGLAND
owned by the Harvard Forest and situated in the town of Winchester, N. H. Due to location within a zone of overlapping of the northern forest and central hardwood forest virgin stands of the region contained a great variety of species, including beech, hard maple, paper birch, ash, hickory, oak and chestnut, together with pine, hemlock and spruce. A knowledge of natural associations of trees, undisturbed by man, is of the utmost importance to the sound development of the art of silviculture as applied to existing volunteer stands or to plantations.

THE PROGRESS OF SCIENCE

THE MARIA MOORS CABOT FOUNDATION FOR BOTANICAL RESEARCH AT HARVARD UNIVERSITY

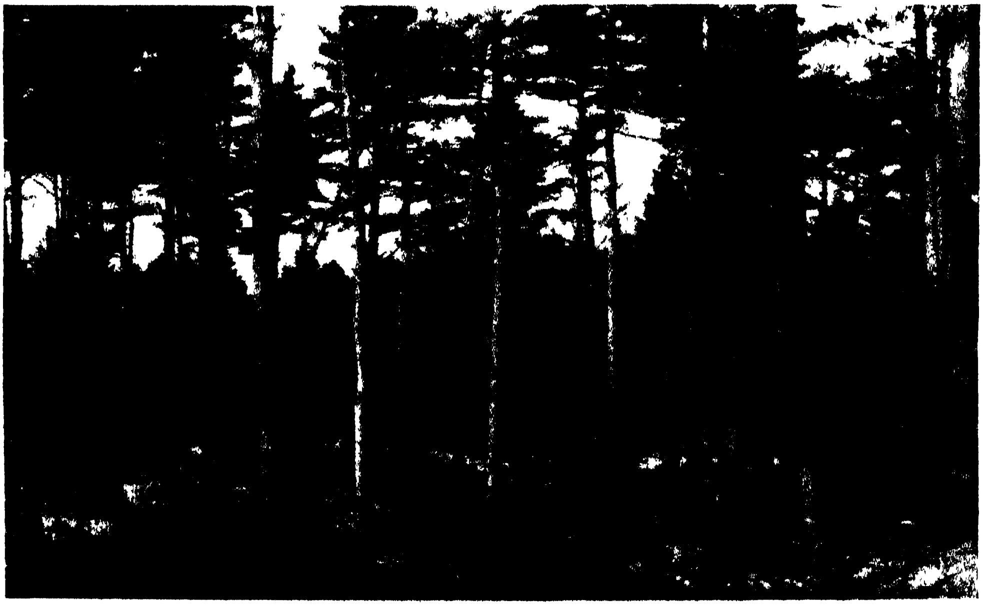
This foundation was established at Harvard University in June, through the munificence of Dr Godfrey L Cabot, of Boston. It is named in honor of Dr Cabot's wife, the initial endowment being $615,773,000. The income from this endowment is to be used in a long-range research program for increasing the production of cellulose and other plant products by plant-breeding, especially tree-breeding, and by the improvement of forest soils. For fifty years the income is restricted to the special purposes above indicated, but all restrictions are removed after that period and the income may then be used for any purpose by the university Because of the interest of the donor in designating the foundation as one for botanical research it is only reasonable to suppose that the income will be used indefinitely within the general field of botany.

Harvard University administers eight separately endowed botanical institutions, these being, in the order of their establishment, the Botanic Garden, the Gray Herbarium, the Bussey Institution, the Arnold Arboretum, the Botanical Museum, the Harvard Forest, the Farlow Reference Library and Herbarium of Cryptogamic Botany and the Atkins Institution of the Arnold Arboretum Four of these are located in Cambridge, two in Jamaica Plain, one at Petersham, Mass, and one at Soledad, Cienfuegos, Cuba The newly established Cabot Foundation fortunately does not involve the establishment of another institution,

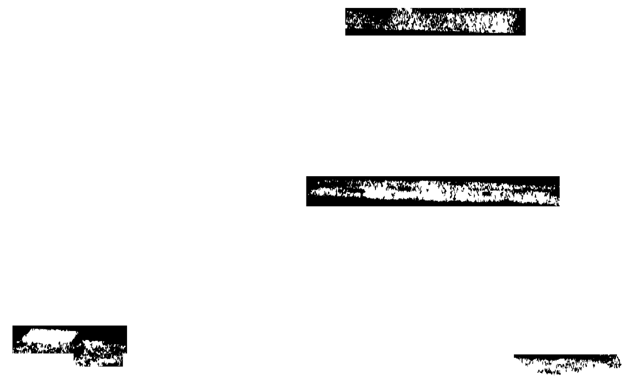
STUDENTS AT THE HARVARD FOREST READING INSTRUMENTS

in a field experiment designed to show the influence of different kinds of forest cover, in this case "old field" white pine, on frost depth, soil temperature, water-holding capacity, rate of snow melting and other factors which govern run-off in the early spring, when floods are most likely to occur. Similar stations were located under a nearby stand of mixed hardwoods and in an open mowing.

A "TRENCHED PLOT" FOR THE STUDY OF SOIL FACTORS
which affect natural reproduction in a stand of white pine and hemlock. By cutting off the tree roots entering the plot a luxuriant development of herbaceous plants and tree seedlings results, because of changed biotic relations in the soil. There is involved a delicately balanced equilibrium between soil organisms with highly complicated relations. How cultural treatments of stand affect this equilibrium is intensively studied in the field and laboratory.



A NEW GENERATION OF WHITE PINE AND HEMLOCK
resulting from the shelterwood method of natural reproduction, in which the new stand is started under the "shelter" of old. So-called preparatory and seed cuttings open up the canopy of the overwood and create conditions favorable for the establishment and early growth of the seedlings. Finally the old stand is completely removed and the new generation fully freed. This method is applied to even-aged stands and gives rise to successive stands of the same form



EQUIPMENT USED IN THE STUDY OF THE EARLY DEVELOPMENT OF TREE SEEDLINGS UNDER MEASURED ENVIRONMENTAL CONDITIONS

Studies using this equipment have shown that Scotch and Corsican pines grow more vigorously than does white pine with equal increases in nitrogen supplies. High nitrogen supplies are necessary for utilization of high radiation intensities At low radiation intensities soil fertility is without influence The unique symbiotic habit of mycorrhizae forming fungi in plant roots is also manipulated in the course of this work

THE HARVESTING OF HEMLOCK

in accordance with the group-selection method of natural reproduction. Instead of being even-aged the stand is composed of groups of trees of different ages. As the oldest groups reach maturity they are cut, and the opening is seeded by the surrounding trees. By this partial cutting system the ground is partly shaded at all times, the young trees are afforded protection, restocking of the openings is assured, fire hazard is kept low, and products may be periodically harvested.

for an organized allocation of funds will be made, as needed, to assist individuals associated with the Harvard Forest, the Arnold Arboretum, the Bussey Institution and the Biological Laboratory Thus practically the entire income from the new Cabot Foundation can be utilized to support direct work on the problems involved without attendant overhead for land, buildings, laboratories, equipment, libraries or senior personnel, Harvard University being already well equipped in material resources essential to the initiation of investigations in this new field.

Dr Cabot has long been impressed with the increasing importance of cellulose both as a substance and as a source of energy. Solar radiation is a primal source of energy, and in the living plant nature has provided us with a marvelous mechanism for storing that energy. Obviously, there are fixed limits to the earth's land area suitable to plant growth, and there is a limit to the number of plants that can be grown per acre The possible answer to the problem of an increased production of cellulose seems to lie in the development of faster growing plants, either because of inherent genetic qualities of individual forms or species or because of improved soils. An investigation of these two lines of attack, particularly in reference to forestry, is now made possible through this recent gift.

The project is an exceedingly complex one, inevitably associated with the many years that constitute a tree generation. It is, however, reasonable to suppose that over a considerable period of time results can be obtained in tree-breeding as striking as those obtained in the breeding of food plants. We thus embark on a single line of investigation that may take several generations of research workers to complete, and we may have confidence that Harvard University has the stability and tenacity of purpose to carry this program through to a distant and successful conclusion.

THE OLDEST CULTIVATED STAND ON THE HARVARD FOREST

twenty-nine years of age, which dates back to the first logging operation conducted under the university's ownership, in 1908. It has received four silvicultural treatments, in the form of weedings and thinnings, which have resulted in a high-quality mixture of trees of valuable species. Through the elimination of the weed trees and the reduction of competition the very best individuals in the stand have been favored from the start, and these are now five to seven inches in diameter and over fifty feet in height.

As at present organized, the Cabot Foundation will have no staff of its own corresponding to the staffs of the eight units associated under the administrator of botanical collections of Harvard University. It will be supervised by an administrative committee, made up of members of the staffs of the units mentioned above, including also members of the Biological Laboratory group. It is planned to develop the involved research program in coordination with existing units of the university and in cooperation with other private and governmental agencies that are interested in this general field.

Investigations have already been commenced under the supervision of Professor K. V. Thimann on methods of vegetative propagation of promising strains, particularly the conifers. Professors E. M. East and Karl Sax have initiated a study of the hybridization of trees by artificial pollination, in order to evolve more rapidly growing strains They will also attempt to induce the doubling of chromosome numbers in selected forms with the objective of increasing the size, vigor and hardiness of woody plants and with the added objective of possibly establishing hybrids that may be propagated by seed instead of by vegetative reproduction Professor R P Gast will continue and amplify his program on the effect of controlled quantities of nutrients and solar radiation on the rate of growth of trees and will extend his investigations to the nutritional qualities of natural forest soils and their improvement; he will also supervise the selection and propagation of the most promising natural strains of different tree species, which are known, in many cases, to vary widely, even within the same species

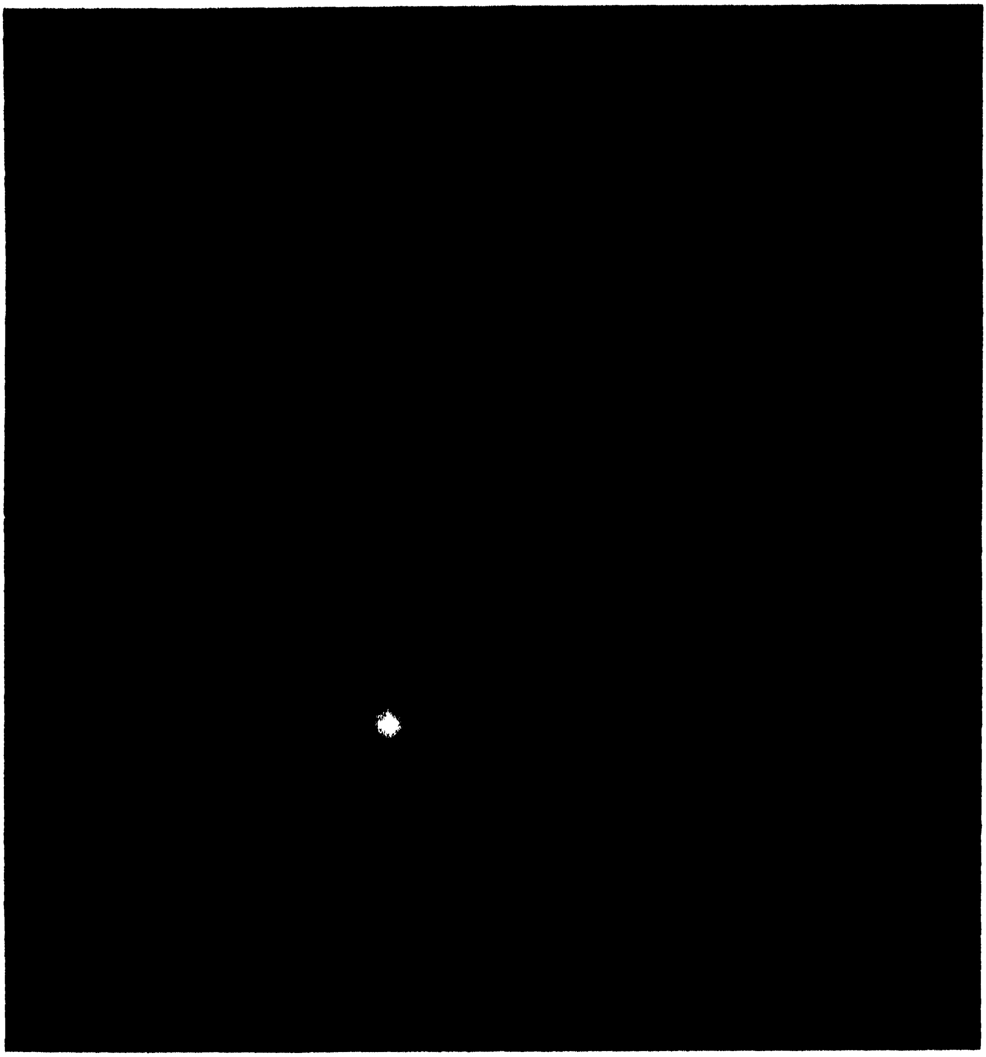
The research program as at present developed is a tentative one, subject to modification, amplification and reorientation as the work develops. For this reason it has not been considered expedient to utilize any considerable amount of the income for salaries of permanent employees, but rather to so allocate the funds that, as desirable or expedient, lines of attack that prove to be unproductive may be discontinued, and investigations in other fields developed.

E D MERRILL,
Administrator of
Botanical Collections
HARVARD UNIVERSITY

THE COMETS OF 1937

THE six comets so far observed in 1937 do not constitute a record-breaking number, but the three rather bright ones have provided considerable interest and activity in the comet world Finsler's Comet has been by far the most interesting because of its comparatively great brilliancy. In recent years there has been a dearth of bright comets Peltier's Comet of 1936 at its maximum was nearly as bright as Finsler's, but unfortunately for both the professional and amateur astronomers the maximum brightness occurred nearly at full moon so that the comet was visible to the naked eye only under the best atmospheric conditions. Finsler's Comet was singularly well placed for good observation Its nearest approach to the earth on the 9th of August coincided so closely with its perihelion passage on August 15 that it remained for several days at an optimum brightness of about fourth magnitude, easily seen but not conspicuous to the naked eye. The moon reached first quarter on the 13th, so that observations were not hampered by any background skylight arising from a bright moon. In addition, the comet's apparent path lay close to the north celestial pole and passed through the handle of the Great Dipper, making the comet a circumpolar object for most of the observers in the northern hemisphere

Although Finsler's Comet did not approach the sun closely, its perihelion distance being about 80 million miles, it possessed a tail more than two million miles long, near the time of its greatest brightness This tail was pointed almost directly away from the sun and was of the long, narrow and nearly straight type. In addition to this principal tail, very conspicuous photographically or with field glasses, there developed in early August a second tail, roughly two hundred thousand miles in length, that was directed about 40° away from the principal tail. This second tail was little more than an elongation of the corona, but was definite enough to deserve the name of a tail. Multiplicity of tails is not an abnormal phenomenon in comets. For example, the Comet of 1744 exhibited twelve tails at one time and the Morehouse Comet in 1908 possessed five tails that rapidly changed in form. The complex processes of ejection of material



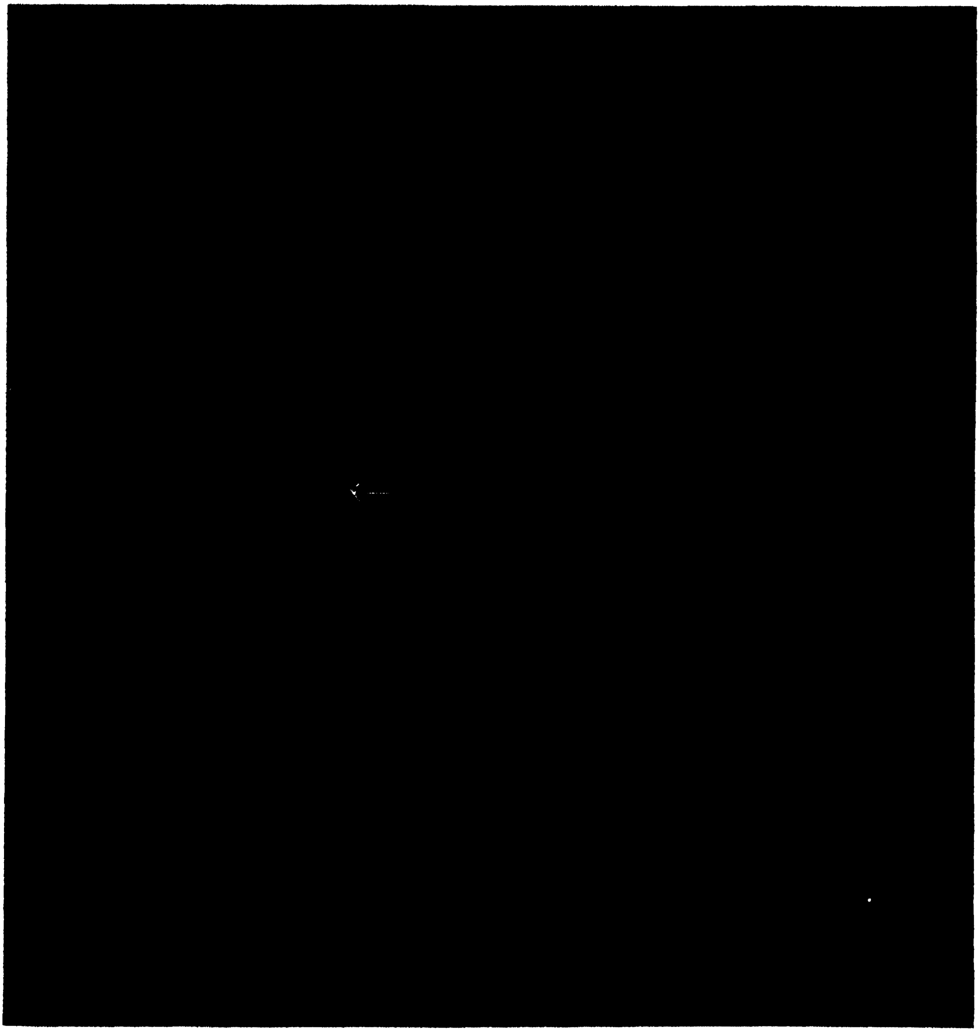
Photograph by L E Cunningham

COMET FINSLER

from a comet's nucleus and the apparently erratic action of radiation pressure produced by sunlight on this material provide ample reason for diversity of form in the head and tail of a comet

At the time of writing no reports have been made concerning any results of spectrographic observations on Finsler's Comet Technique in spectrographic photography of faint diffuse objects has so far progressed in recent years that one should expect a considerable advance in the knowledge of cometary processes from observations of this well-placed bright comet.

Professor Paul Finsler at Zurich, Switzerland, made his discovery on July 4. Preliminary orbit calculation by Mr Leland E. Cunningham at Harvard University and Dr. Allan D. Maxwell, of the University of Michigan, showed that the comet, which was then of the seventh magnitude, would probably attain naked eye brilliancy. The retrograde motion indicated that the period was probably long and that the parabolic assumption



COMET WHIPPLE
ARROW POINTS TO THE COMET

would almost certainly represent the motion for a considerable interval of time To date the deviations from parabolic motion have been too small for the determination of the true eccentricity of the orbit. There is little doubt that the period of revolution is of the order of hundreds of years

The comet of 1937 second in brilliancy to Finsler's was discovered by Dr A. Wilk at Cracow, Poland, on February 27. It was then of the seventh magnitude just below the threshold of naked eye visibility but quickly faded away because of its rapid recession from both the earth and the sun Its perihelion distance was slightly under 60 million miles.

The comet third in brilliancy was discovered by the author in February. Although very well placed for observation and intrinsically quite bright, this comet had such a great perihelion distance, 150 million miles, that it attained a maximum brightness of only about eighth magnitude, too faint to be seen by the unaided eye

It is interesting that all three of these new comets possess very great periods of revolution about the sun, so that none of them will be observed at a second opposition The fourth new comet of the year was discovered by Dr Edwin P. Hubble at the Mount Wilson Observatory on August 4 It is of the thirteenth magnitude but may increase considerably in brightness if the preliminary orbits are correct. Its slow apparent motion and its position near opposition to the sun make the results of the orbit-calculation very sensitive to small errors of observation. Apparently the inclination of the orbital plane to that of the earth's revolution is small, so that there is a good possibility that Hubble's Comet may have a short-period orbit. At the present time the comet is in the constellation of Aquarius, rather far south for good observation at very northern observatories, and its path will probably lie close to the ecliptic at all times, unless there is a close approach to the earth.

Two periodic comets were rediscovered this year. Mr. S. Simiyu at Simada, Japan, found the Daniel Comet in early February. This rediscovery was important because the comet had not been observed at the three oppositions succeeding its discovery in 1909

The periodic comet, Grigg-Skjellerup, was rediscovered by Cunningham at Harvard on April 30, making the fifth apparition at which this comet has been observed since its original discovery in 1902 Its period of five years is the smallest known except for that of the Encke Comet. Although it was not seen at the oppositions of 1907, 1912 and 1917 it has been observed regularly since then.

FRED L. WHIPPLE

HARVARD OBSERVATORY

THE EXPLORATION OF THE UPPER AIR BY THE UNITED STATES WEATHER BUREAU

A NEW system of upper-air exploration, to begin on September 1 at Burbank, Calif, and on September 15 at Fairbanks, Alaska, has been announced by Dr W. R Gregg, chief of the Weather Bureau For several months, radiometeorographs—robot weather observers that broadcast their findings from far above the earth to human observers on the ground—will be released daily with balloons at these two stations.

Those at Fairbanks will pick up first news of cold waves bound for the United States from the North Pole. Those at Burbank will provide upper-air weather news for forecasters all over the country. At the end of the trial period, the bureau hopes to substitute these balloon-borne radiometeorographs for aerometeorographs attached to airplanes that now make routine upper-air soundings at a number of stations from coast to coast

The performance of the new radio instrument will be carefully checked. At Fairbanks an aerometeorograph will be taken up on a plane about every third day Results at Burbank will be compared with those obtained by the Navy's aerometeorograph sent up daily at San Diego

The radiometeorograph promises to remove one of the greatest handicaps to weather forecasting the world over—the dearth of up-to-the-minute information on conditions in the upper air on which to base forecasts. Self-recording meteorographs attached to balloons or to airplanes—now used for the purpose—have serious limitations, according to Gregg Airplanes may fail in bad weather—usually the time when upper-air observations would be most valuable. Seldom do they rise more than three miles. Sounding balloons—gas bags five feet in diameter—go far up into the stratosphere, but usually they do not drop their recording instruments where observers will find them immediately. Every minute counts in getting out the weather forecasts at the six regular forecast centers and special forecasts for fliers at some fifty airport weather stations.

The new robot weather observer—the

result of extensive research here and abroad—reports by wireless the temperature, pressure and humidity of the air through which it passes The bureau expects also to develop radio direction-finding apparatus which will indicate how hard the wind is blowing, and from what direction, at each altitude The observers get all this information almost instantaneously. So far as the record goes, they are not concerned with the instrument's drop back to earth after the balloon bursts at an average height of ten miles. A small parachute between the radiometeorograph and the hydrogen-filled balloon, which has a diameter of sixty inches, makes this drop as safe as possible Some radiometeorographs will be damaged, possibly beyond repair, before they are recovered, and some may never be found The loss of a few is not serious, however.

The instrument consists essentially of a miniature wireless set which broadcasts the responses made by three elements sensitive to atmospheric changes Attached to each element—one responsive to pressure changes, one to temperature changes and one to humidity changes—is a tiny hand or lever, which moves as the element moves. A fourth small hand, kept in motion by a special clockwork, passes over the three other hands, making contacts as it goes. At each contact a signal is broadcast. A receiving set at a ground station picks it up Trained observers translate the time intervals between the contacts caused by changing atmospheric conditions and the regular contacts of the moving arm with fixed points into pressure, humidity and temperature readings

A radio direction finder set up above the receiving set provides information on the direction and velocity of the wind aloft. Radio waves from the moving transmitter in the sky, striking the antennae of the direction finder, permit the observer to determine the height and position of the instrument From a chart of these positions several times each minute the observers compute wind velocity and direction at various altitudes far into the stratosphere

The radiometeorograph observations from Burbank and Fairbanks, going out by radio and teletype, will reach forecast centers and airports almost as soon as they are taken

For accurate translation of the radiometeorograph's signals into temperature, pressure and humidity readings, observers must know how the instrument responds to atmospheric changes This is determined by a preliminary checking—"calibration"—of each instrument before it is released The Weather Bureau will calibrate the instruments going to Alaska, the manufacturer, those used in California

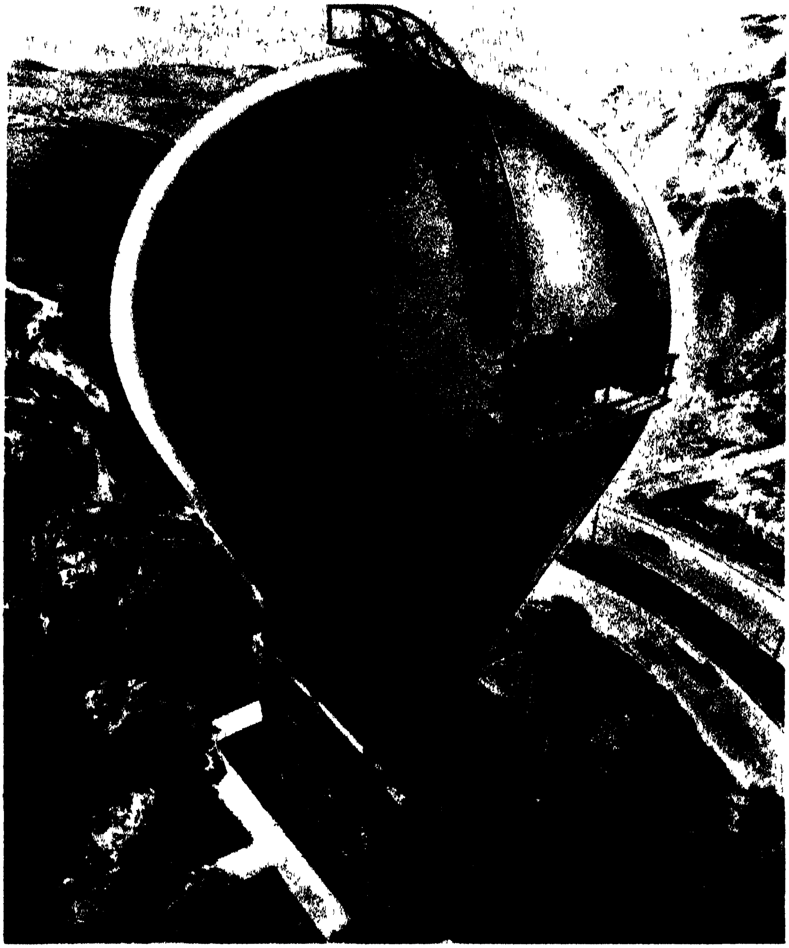
The Weather Bureau has a new cabinet for calibrating its robot observers—a pressure-temperature chamber with the most modern devices for regulating air conditions within Pressure, temperature and humidity in the cabinet are made to correspond with those the radiometeorograph might be expected to meet as it rises through the atmosphere. The time intervals between its signals from the cabinet are noted They provide the basis for evaluating the records obtained on regular ascensions.

The radiometeorographs will be delivered to the Weather Bureau in small lots, so that the manufacturers can immediately incorporate any new developments that will improve performance. Like the first automobile, present radiometeorograph models are open to the improvements and refinements which are bound to come. P N.

EXPLORING THE ATOM

Disintegration of the atom is expected to solve much of the mystery surrounding the structure of matter. It involves adventure in the unknown realms of pure science and promises the rewards of important engineering achievement.

At the East Pittsburgh research headquarters of the Westinghouse Electric



ARCHITECT'S DRAWING OF PROJECTED "ATOM SMASHER'

and Manufacturing Company, there has now been completed plans for the world's largest unit for conducting experiments in the field of nuclear physics. The "atom-smasher," as it is popularly termed, consists of a huge pear-shaped tank, thirty feet in diameter and forty-seven feet long, housing an electrostatic direct current generator and other required parts, including a forty-foot vacuum tube Air within the tank will be held to a pressure of 120 pounds per square inch The entire structure will be about as tall as a six-story building.

Voltages generated in the "atom-smasher" will range to 5,000,000 and beyond. Such high voltage will accelerate ions or particles of matter, shot through the vacuum tube at about a tenth of the speed of light. Then, leaping from the end of the vacuum tube through thin windows of metal, the particles will strike the targets of various metals, at velocities high enough to penetrate the nuclei of the atoms and thus produce nuclear reactions. The results of the bombardment will be counted, measured and identified by special instruments developed for this purpose.

Physicists continue to investigate new processes, energies and sequences of operations that provide nuclear reactions and transmutations of one element into another. By constant progressive steps of experimenting they may learn how to duplicate the changes that occur in nature, how to vary elements and how to create new products Accelerated progress in this direction is expected to result from the data gathered as the Westinghouse "atom-smasher" is put to work

Comparatively recent discoveries have started a scientific revolution which probably will have far-reaching results in discoveries that involve fundamental knowledge, and nearly all such knowledge gained has found practical application

Though we do not know where our investigations in the field of nuclear physics will lead us or exactly what results we shall gain, we do know from the experience of pioneer investigations that in this field are hidden golden nuggets of scientific opportunity

In direct charge of the work will be Dr. William H Wells, who has contributed many new features to the design of the equipment.

L W CHUBB, *Director*

RESEARCH LABORATORIES,
WESTINGHOUSE ELECTRIC AND
MANUFACTURING COMPANY

THE MEETING OF THE BRITISH ASSOCIATION AT NOTTINGHAM

CONTINUING the trend of the 1936 meetings toward the practical application of science, the British Association for the Advancement of Science will feature two group discussions along this line in the 1937 meetings during the first eight days of September The Sections of Geography and Geology will unite in a consideration of the potential resources of the area surrounding Nottingham; these sections will join the Sections of Zoology, Botany, Agriculture and Economics in a program on planning of the land of Great Britain

Nottingham is in the center of an industrial area, providing an admirable location for meetings of this nature When not attending sessions, members will take excursions to observe the hosiery, chemical, mining, tobacco, bicycle and general engineering undertakings in the near vicinity.

Besides aiming toward practicality, the British Association conducts each year an informative program tending to popularize science. This consists of a series of public lectures in various outlying districts, parallel with the regular meetings. The 1937 program includes an address to the Nottingham children by Dr. Alexander Wood on "Noise"; to a Derby audience by Sir Gilbert Walker on "The Science of Sports"; at Lincoln by Mr. R. Kay Gresswell on "Rivers"; at Long Eaton by Dr J. E. Constable on "Everyday Applications of Physics", at Mansfield by Professor J Walton on "Coal and its Origin", and at Newark by Mr T. M Herbert on "Transport of Food."

The presidential address to the entire group will be delivered in Albert Hall by Sir Edward Bagnall Poulton, who was Hope professor of zoology at Oxford from 1893 to 1933. His theme, the history of evolutionary thought as recorded in the meetings of the association, is especially appropriate for a group which maintains Darwin's home as a national memorial. Born in 1856 and educated at Jesus College, Oxford, Sir Edward has long been a student of Charles Darwin and of evolution He was president of the Linnean Society from 1912 to 1916 and is honorary life president of the Royal Entomological Society

Other evening meetings will be addressed by Professor J. Gray, who will discuss the movements of fish; Professor H. Hartridge on "Illusions of Color," and Dr. R. E. Slade on "Grass and the National Food Supply."

Sectional meetings will be held in the University College buildings in University Park. These buildings, which provide not only pleasant surroundings but an open-air swimming pool, were the gift of the late Lord Trent and were opened by His Majesty King George V in July, 1928.

Two functions are scheduled for social diversion. The lord mayor and members of the city council will hold a civic reception at Nottingham Castle on September 2, and the college council will entertain at a garden party on September 7.

The 1937 meeting is the third gathering of the association in Nottingham, the second having been held in 1893 and the first in 1866 The records of the first meeting show that Wheatstone was president of the Section on Mathematics and Physics and that Joule read a short paper on the heating effect of an electric current in a wire. C P. K.

THE FORTHCOMING ROCHESTER MEETINGS OF THE AMERICAN CHEMICAL SOCIETY

THE ninety-fourth meeting of the American Chemical Society convenes in Rochester during the second week of September, under the general chairmanship of M H. Eisenhart, president of the Bausch and Lomb Optical Company. The honorary chairman is Florus R Baxter, who until his retirement was director of the research laboratories of the Vacuum Oil Company.

Seventeen professional divisions of the society and the microchemical section have scheduled sessions On September 8, the society as a whole convenes in the Eastman Theater for a general program to be addressed by three prominent scientific men Dr. E R. Weidlein, director of the Mellon Institute of Industrial Research, Pittsburgh, will deliver the annual presidential address of the Society on Tuesday evening

At twenty-three symposia, special reports of developments affecting industry, nutrition, public health, pure science and education will be presented. Artificial radioactivity and its chemical uses, studies of the chemistry of the earth's crust, low temperature methods and research, chemical microscopy, quantitative spectroscopic analysis and photography will be among the session topics of the division of physical and inorganic chemistry. The National Research Council's insulation committee will join with the division in a symposium on the chemistry and physics of electrical insulation.

Medicinal patents, vitamins and the chemistry and metabolism of fats will be considered by the divisions of agricultural and food, medicinal and biological chemistry. The cellulose division will emphasize research on cellulose derivatives, while the paint and varnish division will feature organic plastics The industrial and engineering chemistry division will hold half-day symposia on "unit processes" and "automatic control."

The characteristic properties and chemical utilization of hydrocarbons will be the chief subjects of the petroleum division. Two days will be devoted by the gas and fuel division to "Gaseous Combustion," during which will be covered the kinetics of ignition, flame propagation, inflammation limits, internal combustion engines, problems in fuel rating and the state of the burned gas.

A wide variety of papers will be heard at other divisional sessions, including investigations dealing with sugar, rubber, water, sewage and sanitation, microchemistry, organic chemistry, fertilizers and colloids. A symposium and informal colloquium on chemical engineering education will be sponsored by the chemical education division. The division of the history of chemistry will celebrate its founding sixteen years ago in Rochester.

All-day trips to the Corning Glass Works, the Taylor Wine Company and the Pleasant Valley Wine Company have been arranged. Industrial laboratories in Rochester, including those of the Eastman Kodak Company and of the Bausch and Lomb Optical Company, will be visited. A. C. S.

THE SCIENTIFIC MONTHLY

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THE BRAIN FROM FISH TO MAN

A SERIES OF CULMINATING PHASES IN EVOLUTION

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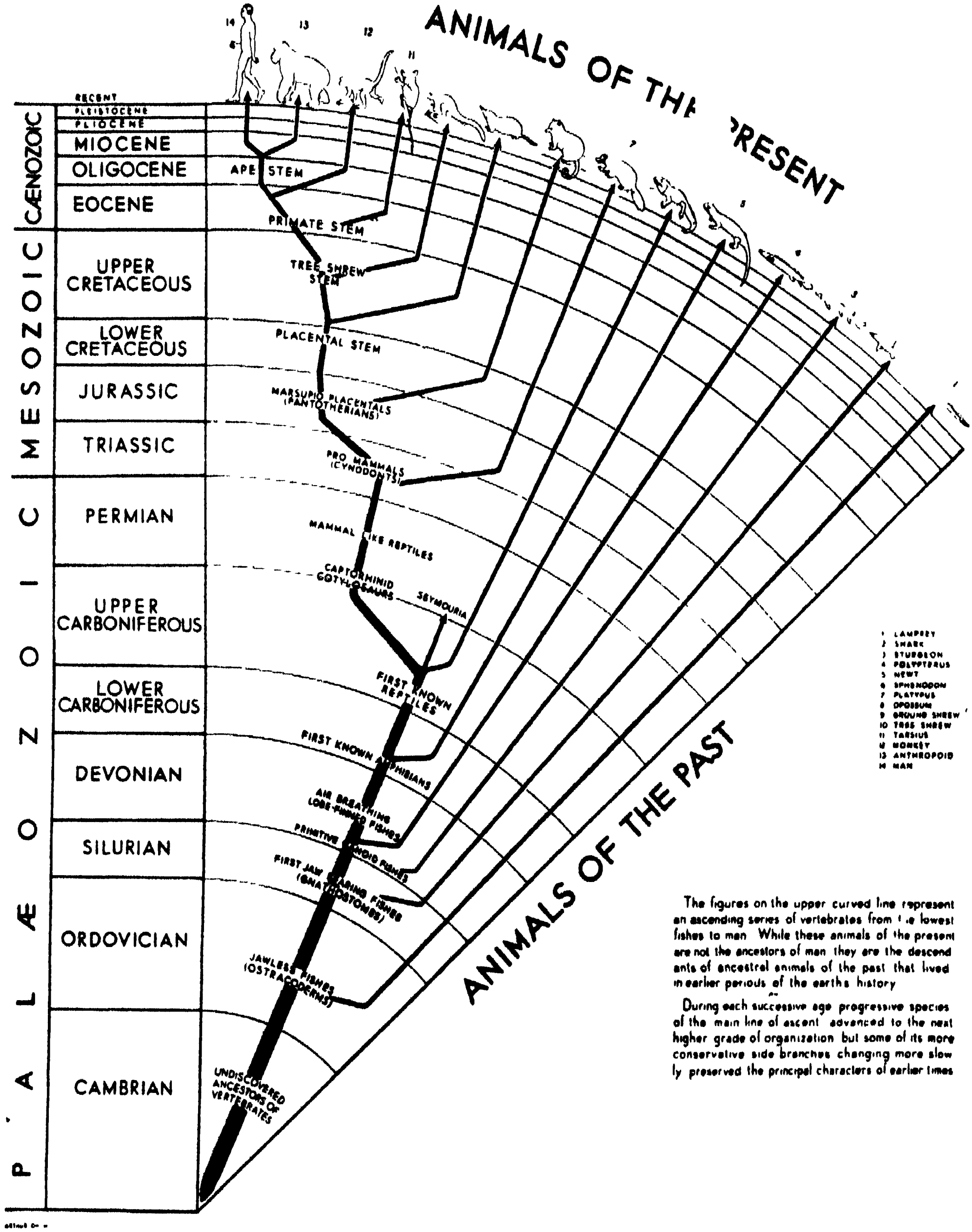
In a recent address I ventured to suggest that the human cerebrum is not yet a finished product, it is, in fact, only some intermediate stage in the ultimate development of the master organ of life.

This suggestion is based upon the evolutionary changes through which the brain has passed. Such changes have been the result of structural modifications which, beginning in the fish, have undergone progressive advances in amphibians, reptiles and mammals until they reached their present culmination in the brain of modern man

A full discussion of these structural modifications would require a voluminous treatise, and therefore it is my purpose to single out certain striking cerebral features in which the effects of evolution are particularly clear.

At first glance it might appear presumptuous to attach such a traditionally objectionable word as "evolution" to the human brain In order to avoid certain prevailing resistances, it may be said that evolution, as here conceived, embraces a much more comprehensive process than that largely current in popular thinking. The implications of this process are not limited to the anthropoids. No scientist to-day believes that any of the living monkeys or apes are ancestral to man. These animals belong to families totally divergent from the human family. For the most part, they have ascended well up into the trees. Here, doubtless, they will remain as unconcerned in human origin as they are above reproach for participation in it

Whatever interest there is in evolution should not, therefore, center in the ape and monkey kinds. The line of our ancestry reaches far back of them through millions of years. We were in the making long before there were any apes on earth. They, in their tree life, merely showed the way which shaped our course toward humanity. To make the proper acknowledgment of our hereditary indebtedness we should recognize in our family tree that highly important line of mammals which first introduced the customs of tree living. Back of them are still older lines which deserve equal ancestral credit. Here are found those animals, without the existence of which we should never have arrived Among these is that vast assortment of creatures which made their appearance in the Age of Reptiles. All these reptilians were, in their turn, indebted for existence to earlier amphibians and fish. Thus the true line of vertebrate evolution leads



The figures on the upper curved line represent an ascending series of vertebrates from the lowest fishes to man While these animals of the present are not the ancestors of man they are the descendants of ancestral animals of the past that lived in earlier periods of the earth's history

During each successive age progressive species of the main line of ascent advanced to the next higher grade of organization but some of its more conservative side branches changing more slowly preserved the principal characters of earlier times

FIG. 1. A chart especially prepared by Professor William King Gregory to show the relations of animals past and present throughout the ages of the earth's history. While the ancestors of the present are not the ancestors of man, they are descendants of ancestral animals of the past. (1) lamprey, (2) shark, (3) sturgeon, (4) polypterus, (5) newt, (6) sphenodon, (7) platypus, (8) opossum, (9) ground shrew, (10) tree shrew, (11) tarsius, (12) monkey, (13) anthropoid, (14) man. Through the courtesy of the American Museum of Natural History.

from fish to man (Fig. 1). Not until we realize and sense the full meaning of this long lineage does the vital—the inspiring—significance of evolution become clear. In this way it is possible to appreciate the irresistible force which has carried animal life onward and upward through the ages This force may be and probably is still at work. It may still carry us upward. In this light an evolution of the brain might prove acceptable. Incidentally, it may contain suggestions concerning further human advancement, possibilities for improvements and readjustments in human relations and behavior In view of existing conditions such an idea might even be welcomed (Fig. 2).

Striking Constancy in the Manner of Brain Development in All Vertebrate Animals

The evidence of this evolutionary process includes numerous features connected with the genesis and growth of the brain, with its basic structural plan, with the gradual dominance acquired by the endbrain and with significant aspects of the external appearance and internal constituents of the brain as a whole.

Conspicuous among these features is the manner in which the brain, indeed the entire nervous system, develops. The ground-plan of this development is singularly constant in all vertebrates. It is exceedingly difficult, however, to detect where and when the actual beginning takes place. But somewhere in that indefinite cell mass which marks the embryonic dawn of a new life, this critical emergence occurs. Then the first signs of the brain can be recognized as a thin plate of ectodermal cells. This early condition marks the *neural plate stage* (Fig. 3).

A few hours later this plate is converted into a long, narrow groove bounded on either side by a rising neural fold, the *neural fold and groove stage* (Fig. 3).

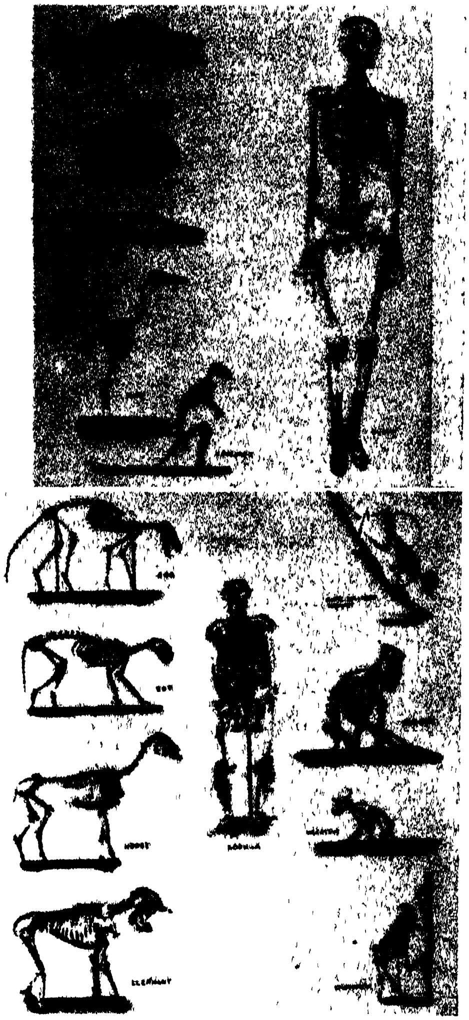


FIG. 2. SIMILARITY OF BONY STRUCTURE FROM FISH TO MAN.

A little later the neural folds meet and fuse down the middle of the back and form a long tube, *the neural tube* (Fig. 3).

Even while this tube is forming, one end of it begins to expand. This is the head-end, and here the brain develops. The rest of the tube forms the spinal cord.

Almost from the beginning, the head or brain-end of the tube begins to specialize. By further expansions it forms

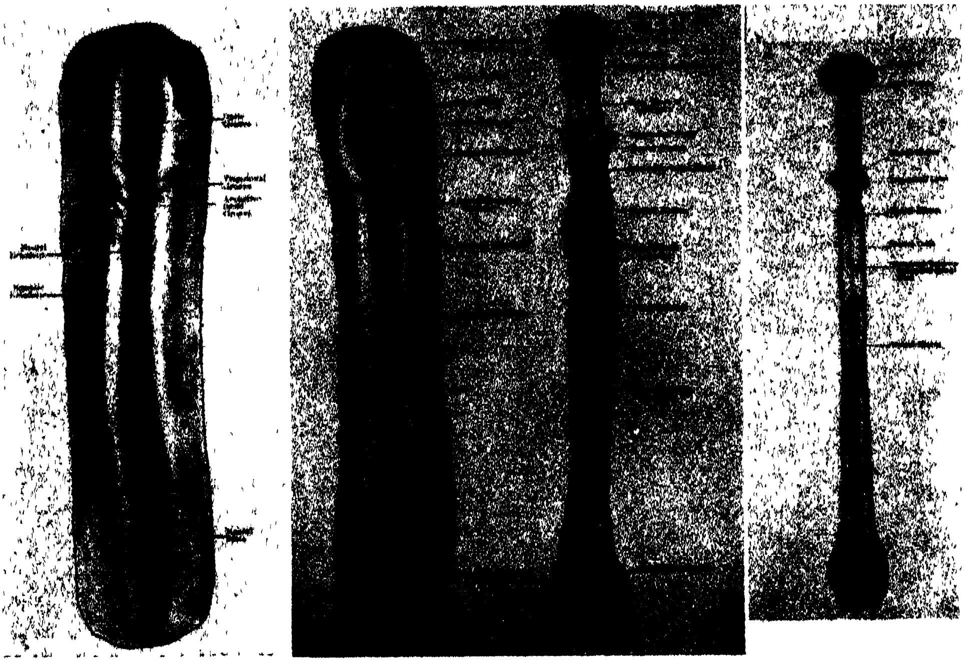


FIG. 3. DEVELOPMENT OF THE VERTEBRATE NERVOUS SYSTEM.
FROM LEFT TO RIGHT, LATE NEURAL PLATE STAGE, NEURAL FOLD STAGE AND EARLY TUBE STAGE, NEURAL TUBE STAGE.

three vesicles called the forebrain, the midbrain and the hindbrain Each of these expanded divisions presides over certain definite functions of life.

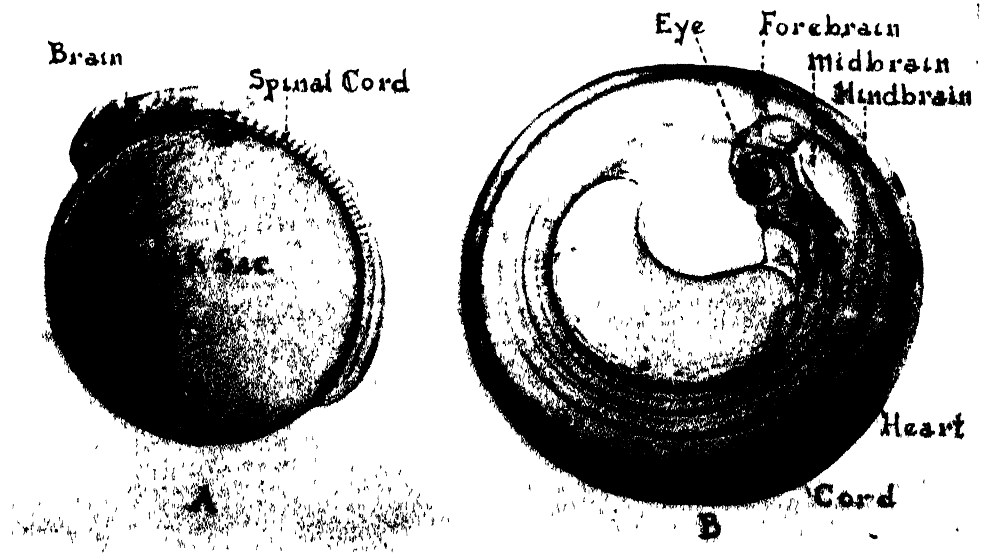
All these important changes, however, are apt to seem static and devoid of their real dynamic significance until they are seen in the actually living and growing animal. It is possible to follow the processes of growth as they appear in motion picture films. Dr. William Beebe and Mr John Tee-Van have succeeded in producing such a film The motion picture is the result of one of the many ingenious methods of study for which Dr. Beebe is famous. The animal used in this case is the deep-sea eel, the species of which is not yet determined, although it is probably closely akin to the moray. After making the catch of the desired eggs, Dr. Beebe devised a means of isolating a single egg. When thus isolated the specimen was brought into a microscopic field at fairly high magnification. By using a moving-picture camera in connection with the microscope, photographs were taken of the growing embryo every minute for seven days. Approximately 10,000 consecutive exposures were made.

The process of growth begins with the rapid movement of cells which determines the gastrula and is quickly followed by the formation of the primitive streak, the neural plate, neural folds and groove and, finally, the neural tube. The embryo as it grows rises in profile above the yolk sac and as it lengthens progressively encircles the yolk of the egg (Fig. 4A and B). Fusion of the neural folds produces the neural tube. The head-end expands and begins to form the three primary vesicles of the brain. The remainder of the tube gives rise to the spinal cord, along the side of which a regular series of muscular segments makes its appearance. Eventually the heart begins to beat, at first spasmodically and then rhythmically; then the first irregular movements of the body occur and later become characteristically vermicular until they are sufficiently frequent and ample to start the fish on its free swimming career with the egg state entirely left behind. During this process of growth the neural and somatic ectoderms have undergone complete separation, the brain and spinal cord have been surrounded by an endoskeleton and a body musculature has been derived from the muscle segments

Although the brain is first recognizable by the special expansions of the neural tube which form the three primary vesicles, it is only a brief time before these early dilated chambers become further modified to form five distinct vesicles. This change gives rise to what is known as the *ultimo-vesicular* stage, through which the brain of every back-boned animal passes in its growth.

Progressive Modifications in the Brain Vesicles

The subsequent modifications of these five ultimate vesicles are of such major importance as to require a familiarity with them, at least by name Thus the *endbrain* consists of two relatively large sacs of neural tissue which open into either side of the *interbrain* by two apertures later to become the foramina of Monro. It is not difficult to anticipate that these endbrain sacs are destined to become the great hemispheres of the cerebrum. In their early development, however, they are not especially prepossessing features of the brain Immediately behind the interbrain is the *midbrain,* and following it are the *hindbrain* and the *afterbrain.* Important as are these labels for the five cerebral divisions, it is equally essential to bear in mind the chief dynamic meaning of each vesicle. For example, the endbrain, in its most primitive form, is almost exclusively devoted to the sense of smell This condition is true in all fishes The interbrain takes charge of integrating sensory impressions coming in from the body. These impressions form the basis of what is, perhaps, the most important of all the senses, namely, *body sense.* The midbrain, in the lowest animals, predomi-



—*Through the courtesy of Dr. William Beebe and Mr John Tee Van*

FIG. 4. EMBRYONIC STAGES IN THE DEVELOPMENT OF THE CENTRAL NERVOUS SYSTEM OF A DEEP SEA EEL.

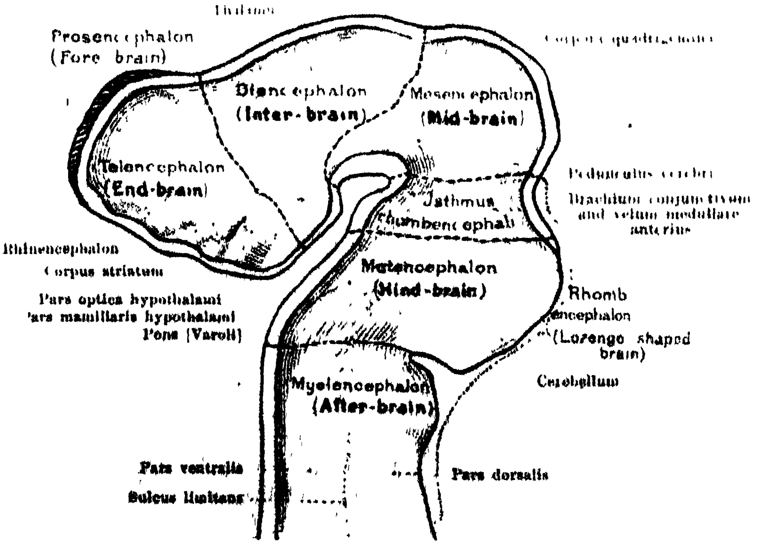


FIG. 5 THE FIVE PRIMITIVE VESICLES OF THE BRAIN (MODIFIED FROM SPALTEHOLZ).

nates in size over the other vesicles and has its great importance in the fact that it presides over the sense of sight. The functions of the hindbrain are body-balance and muscular coordination. The afterbrain regulates the activities which enter into the essence of life, such as breathing and beating of the heart.

The operating agents in all these five vesicles consist of nerve cells and the nerve fibers connected with these cells by means of which the brain carries on all

—Through the courtesy of the American Museum of Natural History

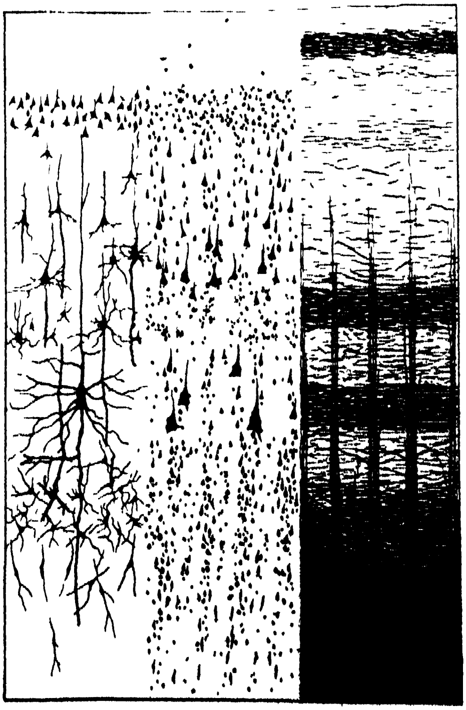
FIG. 6. LOBE-FINNED FISH SHOWING AN EARLY, PARTIAL ADAPTATION TO LIFE ON LAND.

its activities. If any analogy is at all permissible it might be said that these nerve cells are like minute batteries generating, transmitting and receiving nerve impulses.

The five-vesicle arrangement is the structural set-up, even in the lowest of vertebrates, the cyclostomes. It also holds good for all the fish. Not only is this architectural plan constant in fish, but the functional assignment to each vesicle is equally invariable. Indeed, so deeply committed are most of the fish to this structural plan and the functional executions dependent thereon that only a few of them retain any potentiality for further progressive development. In a very true sense the great order of sharks has developed a brain which, so to speak, has led them into a blind alley so far as evolutionary progress is concerned. In these animals the endbrain, which must be regarded as the vanguard in all progressive strides, is so irrevocably involved in the sense of smell that it has been deprived of the plasticity necessary to develop more complicated functioning. This structural inflexibility is likewise true of the bony fish. One exception to this uncompromising adherence to brain development may be found in the order of lung fish or lobe-fins (crossopterygians) (Fig. 6). Here the endbrain retains many characteristics of the primitive vesicles; it is less solid, more saccular in form and embedded in a rich meshwork of blood vessels. The very primitiveness of such an endbrain facilitated if it did not actually invite the modifications apparent in the next advance of cerebral evolution.

In amphibians like the frogs, a new sensory pathway for hearing made its appearance. This added mechanism created the need for additional developments in the brain, and then the reptiles, going a step further, introduced a more potent arrangement of nerve-cells by forming the earliest cortex of the endbrain.

The formation of a cortex of any kind in the brain seems to be the supreme device for producing the most efficient type of neural mechanism. The secret of cortical formation, whenever it occurs in the brain, appears to lie in the fact that the nerve cells and fibers are disposed in a series of layers and not diffusely clustered together. This stratification facilitates the highest degree of cooperation between the various layers of nerve-cells (Fig. 7). Such cortical arrangement of nerve-cells is actually an ancient device in the development of the brain. It has been a characteristic of the midbrain and, to a somewhat less degree,



Through the courtesy of Drs. Strong and Elwyn

FIG. 7. The stratified "cortical arrangement" of nerve cells and fibers in the neocortex which, by comparison with the "nuclear arrangement" in other parts of the nervous system, greatly amplifies the possibilities of intercellular communication and thus provides for more extensive utilization of nerve impulses.

of the hindbrain as far back as the very earliest vertebrates But the appearance of nerve-cells disposed as stratified layers in the walls of the endbrain was an important departure in the development of the cerebrum—a decisive step toward the climax of brain evolution. Whatever other significance it may have had, the appearance of the early endbrain cortex in reptiles, called the *archicortex*, provided a strong impulse for the next great step which was taken by the mammals, namely, the eventual predominance of the endbrain Once established, this predominance drew its chief potency from the introduction of what has been called the "last word" in grain organization, the *neocortex*.

PROGRESSIVE DOMINANCE OF THE ENDBRAIN

These, in brief, are the stages through which the cerebrum has passed in reaching that transition which resulted in the predominance of the endbrain. The several phases of this progress may be accurately estimated by determining the comparative surface extent of the main vesicles in different classes of animals.

TABLE I
COMPARATIVE SURFACE EXTENT OF THE VESICLES IN DIFFERENT CLASSES OF ANIMALS

Animal	Encephalic index (per cent)		
	Fore brain	Mid-brain	Hind-brain
Fish—salmo-salar	19	43	38
Amphibian—fish	47	27	26
Reptile—alligator	41	25	34
Rodent—rabbit	68	0.5	27
Carnivore—dog	72.5	0.5	27
Anthropoid—gorilla	87	0.5	12.5
Human—man—2-year child	90.5	0.5	0.9

TRANSITION FROM NUCLEAR TO CORTICAL PREDOMINANCE

In spite of the fact that cortical formation has an antiquity in the midbrain which goes back to the earliest fishes, the reactions of these animals were in no small measure controlled by the nuclear aggregations in the brain stem and spinal cord. In consequence of this largely nuclear regulation[1] of its energy turnover, the fish possesses a limited power to withhold its actions. Impressions from the outside world produce, in the main, almost immediate responses In all events, the reactions tend to be rapid and preclude a large range of acts which characterize more deliberate and thoughtful behavior. The brain mechanism for this ample kind of life was not yet present in this stage of animal development. It began to make its appearance, however, when certain fishes (crossopterygians) assumed a partial adjustment to life on land These adventurous pioneers managed to crawl out of the muddy waters at times when there was a lack of oxygen or when the supply of food was insufficient. They set on foot the progressive changes which ultimately gave rise to the fore and hind limbs of such amphibians as the frogs. When these latter animals made their appearance nearly all the fundamental problems of the vertebrate brain had been solved. There was still need for certain expansions and refinements in brain power, and these, in some part, were produced in the next succeeding Age of Reptiles. The ancient habit of highly rapid reaction which imposed serious limitations on the activities of the fish had not been entirely overcome either by the amphibian or by the reptile. These animals still lacked the brain machinery needed for the more deliberate and varied reactions of the most effective kind of life. They had not altogether escaped from the ancient tyrannies of automatic response and reflex reaction. And yet the reptiles were headed in the right direction Their acquisition of an archicortex was obviously a sign of progress. This primitive type of cortex is usually considered a development in the interest of the sense of smell I have suggested that it is also connected with visceral sense, that is, with projections upon the endbrain intended to elaborate impressions from the stomach and intestines, the heart and lungs, the urinary and sexual apparatus

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[1] For convenience of description "nuclear regulation" of behavior is used in contra distinction to "cortical regulation" to indicate the difference between the more immediate reflex reactions characteristic of the spinal cord and the more highly coordinated control of the cerebral cortex. A nucleus in the central nervous system, such as the hypoglossal nucleus, the red nucleus and the facial nucleus in the brain stem or the extensor and flexor nuclei in the spinal cord, consists of an aggregation of nerve-cells clustered together to form a well-defined group. Their reactions are limited both in the time and variability in their responses. Cortical structures, on the other hand, have greater plasticity in all aspects of their reactions.

There can be no doubt that the endbrain offers the greatest opportunities for cortical expansion, and here the mammals in time introduced the final detail of brain perfection The outcome of this perfecting detail was the addition of a brain mechanism never possessed by animals before this time and in fact, in the strict sense, never possessed by animals other than the mammals. New and large areas of the cerebral hemispheres now came into existence to form the gray matter of the *neocortex* covering each hemisphere. In this way billions of new nerve cells were added to the brain. Their mere addition was of greatest importance. Even more important was their orderly arrangement in layers and their intimate connection by nerve fibers. With the development of this neocortex in mammals new and greater capacities to react became possible.

PROGRESSIVE MODIFICATIONS OF THE NEOCORTEX IN MAMMALS

When the mammals became possessed of that invaluable brain equipment, the new cortex, they at once began to turn it to their own advantage. It may be more correct to say that the neocortex opened up new avenues of opportunity which the mammals were quick to follow. At any rate, they became great adventurers and great specialists. What adventurers and specialists they have been is shown by the fact that they have occupied every one of the twelve habitat zones on land or in the water. Whales and porpoises have invaded the seas to make their dwelling places. Seals and their kind live partially on land and partially in the water. Hoofed animals inhabit the plains and forests. Bats and flying squirrels find conveyance through the air Moles and burrowing animals have their homes underground. The meat-eaters have scented out every corner of the earth and carry on their hunting expeditions under the guidance of a wily brain. But however varied the mammals have been in their habits they have not all capitalized their neocortical powers to the same degree. In some animals, like the opossum, the rat and the rabbit, the pattern of the neocortex is extremely simple The surface of the endbrain is smooth and unfurrowed. Because of this fact the brain is called *lissencephalic*. Certain mammals, by contrast, have brains which are more or less richly convoluted and hence called *gyrencephalic* What is the significance of these two different types of mammalian hemispheres? In the gyrencephalic brain the surface is thrown into numerous irregular convolutions which greatly increase the areas capable of containing nerve cells and fibers. The lissencephalic brain, on the other hand, being by comparison less extensive in surface, is correspondingly less rich in nerve cells and nerve fibers. The functional meaning of these two types of brain is easily discerned in the differences of behavior between a gyrencephalic and a lissencephalic animal.

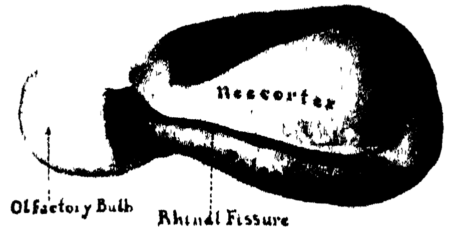


FIG. 8. RECONSTRUCTION OF THE BRAIN IN THE ADULT OPOSSUM TO ILLUSTRATE THE POSITION OF THE RHINAL FISSURE AND THE SHARP BOUNDARY WHICH IT FORMS BETWEEN THE NEOCORTEX AND THE PALEOCORTEX.

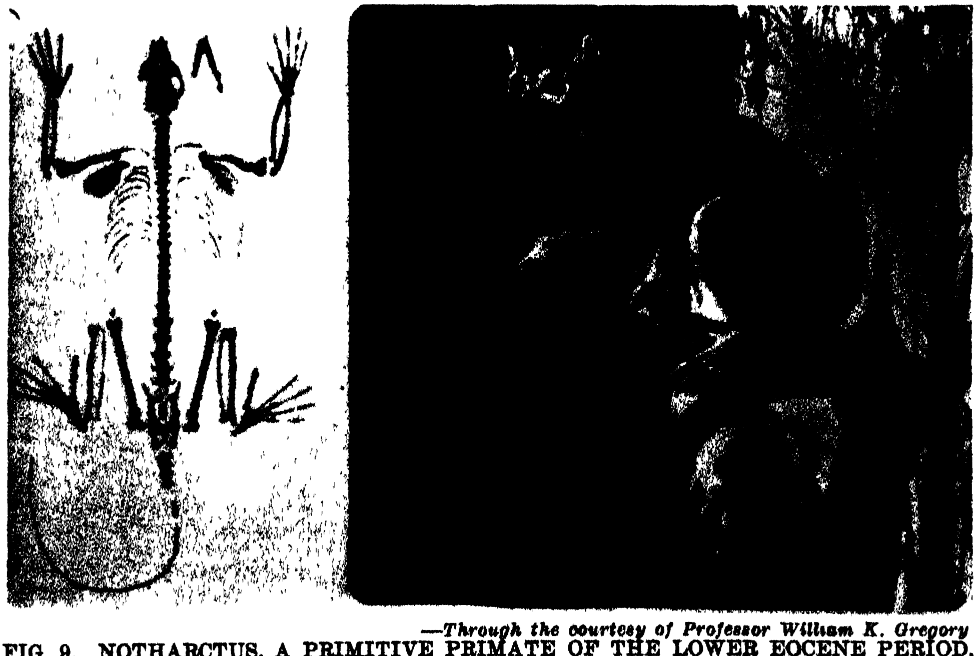
At this point it is appropriate to consider the cerebral assets possessed by the mammals in comparison with lower animals There can be little doubt concerning the increased brain capacities of all mammalian orders. When the actions and capabilities of such mammals as dogs, horses, elephants or any of the cat family are compared with those of the bird or the snake or the fish, the marked differences speak for themselves. The dog, for example, has by comparison with lower vertebrates a greatly increased capacity for getting on in life. He is capable of adapting himself to many complications incident to his association with man. He has an ample and varied repertoire of accomplishments. He is capable of learning many intricate performances. In general, such adjustment and learning power is true of most of the higher mammals. It is particularly true of those having a highly developed neocortex. Even aquatic mammals, like seals, show a remarkable degree of adaptability. They are among the most interesting of trained performers. A casual glance is sufficient to show what an excellent, convoluted cortex they possess. Even in spite of their huge proportions and awkwardness, elephants are capable of remarkable adjustments. Their cortex is also highly developed.

Yet, however decisive the mammalian superiority of brain power may be by comparison with lower vertebrates, most mammals must be credited with distinct liabilities as well. They are held down by handicaps, restrictions and limitations of their own. They may be well adjusted to life in the water, in the air, on the plains, in the forest or underground, but their own specializations hold them to specifically restricted adaptations. Such things as may be done with hoof and paw, wing and flipper, head and trunk they are able to do well But here their opportunities for progress cease.

Capacity for Adjustment Indicated by Three Great Fissures of the Brain

The story of progressive mammalian adjustment is distinctly outlined by three great fissures which occur in the hemispheres The first of these is the *rhinal fissure*, which is the earliest to appear during development and also the most primitive of all cerebral fissures. It extends backward along the outer surface of the hemisphere from the base of the olfactory bulb to the occipital region. Its course runs nearer to the base than to the vertex of the hemisphere. In lower mammals, like the opossum, rat and rabbit, it is a prominent feature of the brain, but its true significance becomes clear only upon microscopic examination (Fig. 8). Then it is seen to form an important functional boundary line. It separates the neocortex, which is situated above it, from the paleocortex, originally an olfactory part of the brain, which lies below. As the neocortex gradually assumes its full development in higher mammals, the paleocortex is more and more forced downward into the basal surface of the brain and finally is lost to view on the lateral surface of the hemisphere. The gradual disappearance of the rhinal fissure goes hand in hand with the progressively increasing dominance of the neocortex in the control of the animal's behavior.[2]

The Sylvian fissure is the landmark which dominates the convolutional pattern of most mammalian brains. The convolutions of the hemisphere form more or less complete arches about it. If it were permissible to make a mammalian grouping into lower class, middle class and upper class mammals, the cerebral cortex of the first group would show a rhinal pattern, the second group would have a Sylvian pattern. The third group or upper-class mammals is distinguished by the presence of a long vertical fissure which passes obliquely across the outer surface of the hemisphere and divides this surface into two nearly equal halves. This dividing line is the *Rolandic fissure,* and the fissural pattern which it produces is the Rolandic pattern. No single factor has been more influential than this Rolandic fissure in determining the characteristics of the upper-class mammals which are known as the Primates. By them many of the handicaps which restricted other mammals were in large measure dissipated. This group of animals took its initial and main advantage from the fact that it assumed a life in the trees. Tree living of this kind began, according to Professor Gregory, with the late Paleocene representatives of the tree-shrew, and perfected arboreal primates first appeared in the lower Eocene Notharctus is such a primitive primate. Its hands and feet were of the grasping type similar to more recent primates like lemurs and monkeys (Fig. 9).



—*Through the courtesy of Professor William K. Gregory*

FIG. 9. NOTHARCTUS, A PRIMITIVE PRIMATE OF THE LOWER EOCENE PERIOD, WHOSE HANDS AND FEET SHOW THE EFFECTS OF ADAPTATION TO ARBOREAL LIFE.

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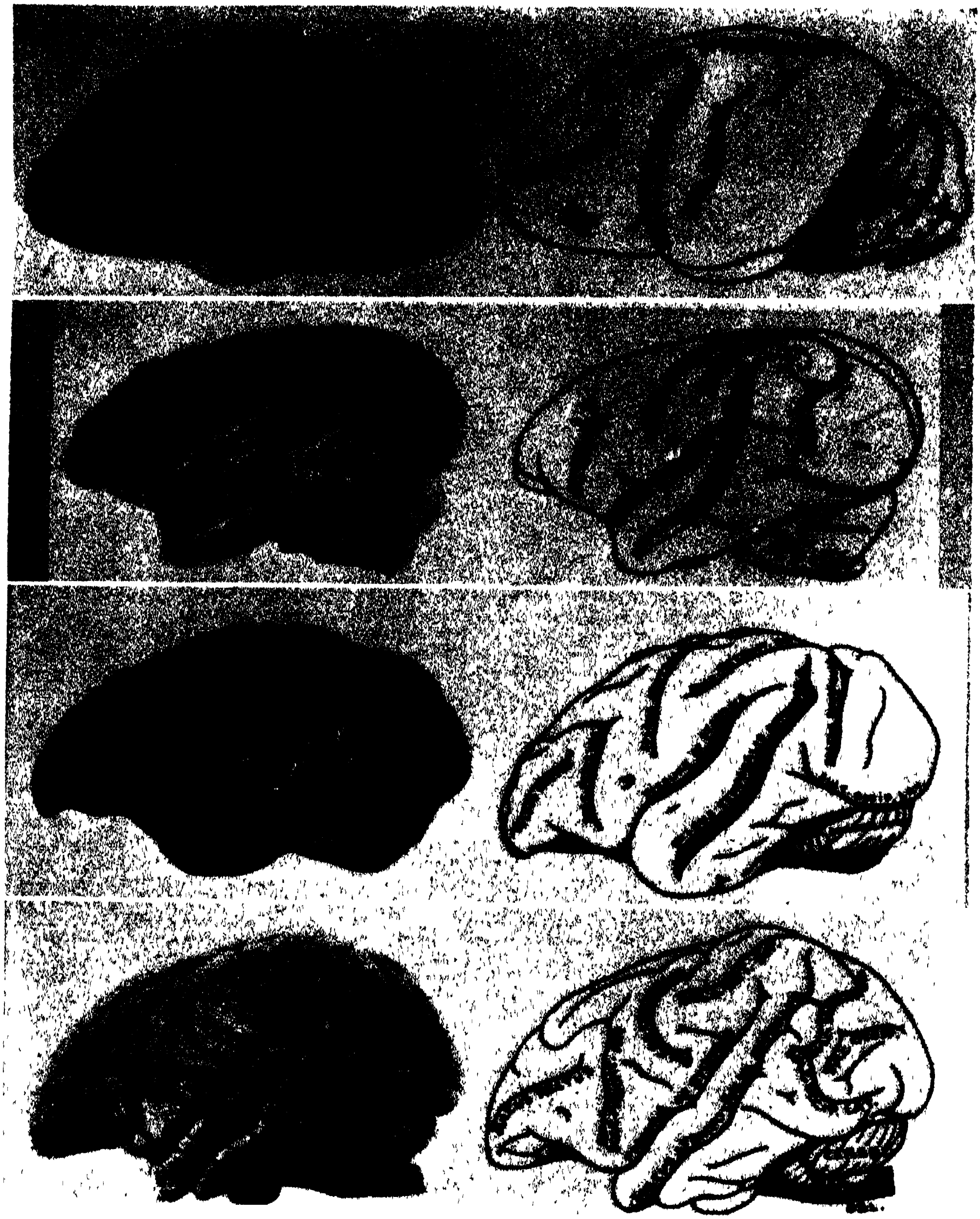
[2] In discussing the fossil brains of some early tertiary mammals of North America, I have called attention to the significance and primitiveness of the rhinal fissure. This fissure appeared as a prominent feature in the brain casts of six different groups of mammals, including Amblypods, Condylarths, Perissodactyls, Artidactyls, Carnivores and Rodents. Most of these did not become extinct until the Oligocene. In the earliest and most primitive of these mammals, the rhinal fissure alone appears on the lateral surface of the hemisphere.



LEFT HEMISPHERE OF THE BRAIN OF FOUR MONKEYS.

FIG. 10. 1st row (top), one of the lowest primates, the lemur monkey. c, sulcus centralis (fissure of Rolando); sulc. orb., sulcus orbitalis; sulc. temp. sup., sulcus temporalis superior. 2nd row, left hemisphere of the brain of the South American howling monkey, Mycetes seniculus. Obl, oblongata; ram. post., ramus posterior to superior temporal sulcus; sulc. prect. inf., sulcus precentralis inferior; sulc. ret. inf., sulcus retrocentralis inferior. 3rd row, the East Indian monkey, *Macacus rhesus*. Sulc. occip. lat., sulcus occipitalis lateralis; sulc. prect. inf., sulcus precentralis inferior; sulc. retroct. inf., sulcus retrocentralis. 4th row, the gibbon, *Hylobates hoolock*. Cerebl., cerebellum; obl., oblongata; sulc. occip., sulcus occipitalis; sulc. occip. lat., sulcus occipitalis lateralis; sulc. prect. inf., sulcus precentralis inferior; sulc. ret. sup., sulcus retrocentralis superior; sulc. simiarum, sulcus simiarum.

Dawn and Development of the Primate Brain

In many of their essential features these animals resemble men, and for that reason they are listed under the common name of *primates* in the same bracket with mankind. As in other spheres of life there are class distinctions among the primates. The lowest of them include the lemurs, tarsiers and all the New World monkeys. In the next higher rank are the monkeys of the Old World. The proanthropoid and anthropoid apes occupy the highest grade immediately below man. They include the gibbon, orang outang, chimpanzee and gorilla. In appearance and habits these animals are nearest to man. It is in their brain, however, that they make the closest approach to the human race. But this approach is achieved through a series of graded stages which have their beginning in the humble lemurs. It is here that the dawn of the primate brain may first be discerned. The lowest of the primate tribes show little advance over the lower mammals. The lemurs, standing farthest down the scale, give

—Through the courtesy of the American Museum of Natural History

FIG. 11. HABITAT GROUP, ORANG-OUTANG, SADONG RIVER, BORNEO.

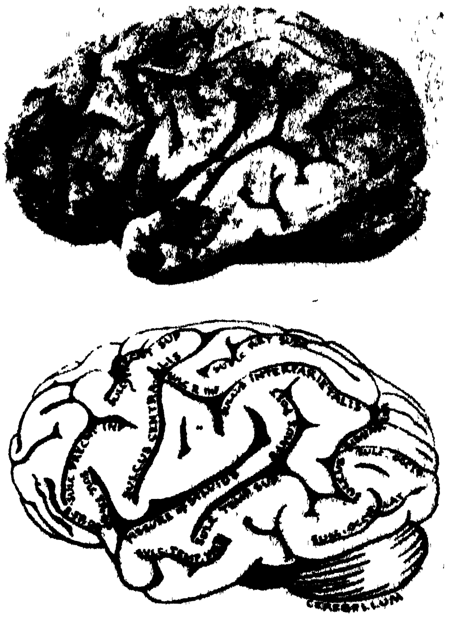


FIG. 12. LEFT HEMISPHERE OF THE BRAIN OF THE ORANG-OUTANG.

almost no signs that they are the real beginning of the long climb. Their endbrains are built definitely on the Sylvian pattern and although the rhinal fissure has almost entirely disappeared from the lateral surface of the hemisphere, only a faint trace of the Rolandic or central fissure can be detected (Fig. 10).

Brain and Behavior of the Lowest Monkeys

In following the progressive stages through which the endbrain passes in the primates, it will be necessary to observe the changes in certain lobes as well as the disposition of these three important fissures. In lemur the frontal lobe, which lies in front of the Rolandic fissure, has only the scantiest representation. The parietal, temporal and occipital lobes, on the other hand, are prominent.

Certain of the lowest monkeys, in the South American group (Cebidae) have, however, taken bold strides forward. The brain of the howling monkey, for example, has a definite primate appearance. No longer does the Sylvian pattern prevail. The Rolandic fissure has become conspicuous, and consequently the frontal lobe is now a prominent feature of the hemisphere. This advance can not be overestimated. Now for the first time it is possible to see foreshadowed that region of the brain upon which was founded not merely the Age of Man but more particularly the Age of the Frontal Lobe (Fig. 10). The parietal and temporal lobes are well represented, and the occipital lobe has acquired a new boundary which runs a somewhat spectacular course in the rest of the monkeys and apes. Professor Thorndike has made most careful studies of the behavior of several different species of South American monkeys. He believes that they represent a certain advance from the more generalized mammals toward man. All this is an advance due to the brain acting with increased delicacy.

Brain and Behavior of the Intermediate Monkeys

A good example of these monkeys is the Macacus or Indian monkey. Dr. Kinnaman, who has made studies of their mentality, believes that they have attained a higher level of intelligence than the New World monkeys. Professor Thorndike and Dr. Hobhouse maintain that macaques have some limited powers of reasoning. Professor Yerkes has expressed the view that the macaques may have a certain number of limited ideas.

The brain of these monkeys shows definite advances. Not only are the fissures deeper and better defined, but the several lobes are larger and more extensively convoluted (Fig. 10).

Brain and Behavior of Gibbon and Orang Outang

Manlike tendencies are still more pronounced in the proanthropoid and anthropoid apes. Certain traits of this kind are obvious in the gibbon, which is able to stand up, walk and even run upon its hind legs. In the trees the locomotion of these animals is different from that of other monkeys. The gibbons, in this act, employ the arms almost exclusively, swinging from branch to branch with the legs tucked up under the body. This is an important and provocative change in the arboreal methods of transportation. In the first place, swinging from one limb to another elongated the forearms and fingers. The second effect produced by this kind of locomotion, which is called *brachiation,* was the progressive drawing of the body more and more into the erect posture (Fig. 10).

Another even more man-like ape is the orang outang. When full grown he stands a little more than four feet in height. Professor Yerkes has contributed important studies based on intelligence tests applied to the orang. These tests were devised on what is known as the "multiple choice system" and used with the partly grown orang, "Julius" This anthropoid continually endeavored to gain some insight into every test situation. Although slow, he showed that the brain had at length attained the development necessary to the production of real ideas (Fig. 11).

In the gibbon and more particularly

-Through the courtesy of the American Museum of Natural History

FIG. 13. HABITAT GROUP OF CHIMPANZEES.

in the orang the parietal, temporal and occipital lobes have increased in prominence. At this stage it is possible to speak of a well-developed frontal lobe. The gradual emergence of this lobe is one of the features in the anthropoid which leads up to the outstanding characteristic of the human brain (Fig. 12).

BRAIN AND BEHAVIOR OF THE CHIMPANZEE

The chimpanzee has an established reputation for many valuable qualities. He is a performer of no mean talents and often as a comedian is able to earn a large salary. He is likewise famous as an acrobat. One of the best studies of the chimpanzee comes to us as an echo of the great war. Some years ago the Prussian Academy of Science established at Teneriffe in the Canary Islands a special station equipped for the study of the great manlike apes. It was here that Professor Köhler found himself during the war, and here he remained interned with nine chimpanzees for two years. As a result of many ingenious tests he found that the animals were able to learn the use of certain implements and even to construct instruments to aid in obtaining food. In many respects, such as playing and hunting, the animals had numerous human resemblances. Being of a buoyant and mirthful nature, the apes derived evident pleasure from clowning and masquerade. Perhaps their most constructive abilities were shown in their building propensities, which were brought into play under the urge of obtaining food. At such times they built tower-like structures by piling one box on another so that they could reach bananas suspended above their heads. Their cooperative efforts in these enterprises were invariably poor, for no sooner was the tower built than some mischievous operative would knock it down. Professor Yerkes's studies at Yale on the larger anthropoids and in his famous breeding station in Florida have added highly controlled tests to these early experiments. It is his opinion that even in the complex activities of cooperative effort the chimpanzee may acquire a degree of insight sufficient to make him an effective coworker in undertakings demanding the combined contributions of several individuals (Fig. 13)

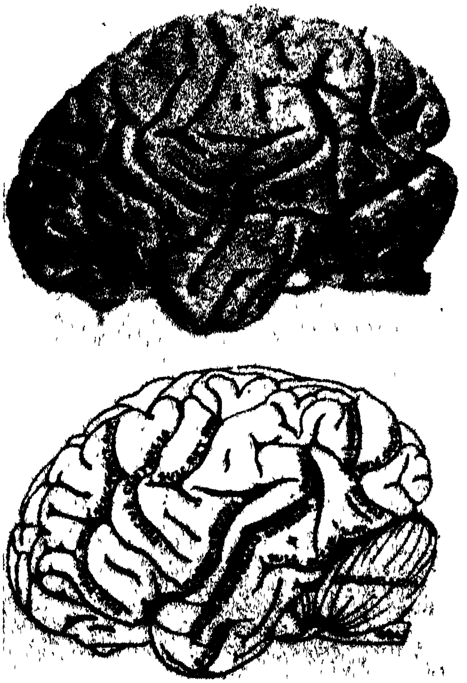


FIG. 14. LEFT HEMISPHERE OF THE CHIMPANZEE.

Should doubts remain concerning the superior, almost human capacities of the chimpanzee, these may soon be put at rest by inspection of his brain. This organ is human in miniature. It reveals the neocortical means by which this animal has acquired his new and extensive powers of learning, his greater understanding, his better capacity for adjustment.

The Rolandic pattern characterizes the fissural arrangement in the neocortex. All the fissures bear a close resemblance to those of the human brain. The lobes are highly convoluted and are disposed much as in man, except that the

—From Miss Alyce Cunningham's description of John Daniel's behavior

FIG. 15. THE YOUNG GORILLA, JOHN DANIEL I,

PORTRAYED IN A FRIENDLY ATTITUDE WITH A LITTLE PLAYMATE.

convolutions in chimpanzee are less complex. The frontal lobe is more extensive than in the orang outang or any of the lower primates (Fig. 14).

Brain and Behavior of the Gorilla

The largest member of the ape world is the gorilla. There is some dispute as to the place he occupies among the primates and also as to what rating his intelligence deserves. Neither of the questions can be settled at the present time. For many centuries the gorilla has had an unsavory reputation because of his savage disposition. The celebrated explorer, Mr. Carl Akeley, felt that this huge and ungainly animal has been done a real injustice in this respect. Instead of being an incorrigible brute he is in reality timid and retiring. Some young gorillas have been subjected to prolonged observation. One of them, called John Daniel the First, was found by Miss Alyce Cunningham in the show window as a Christmas advertisement of a well-

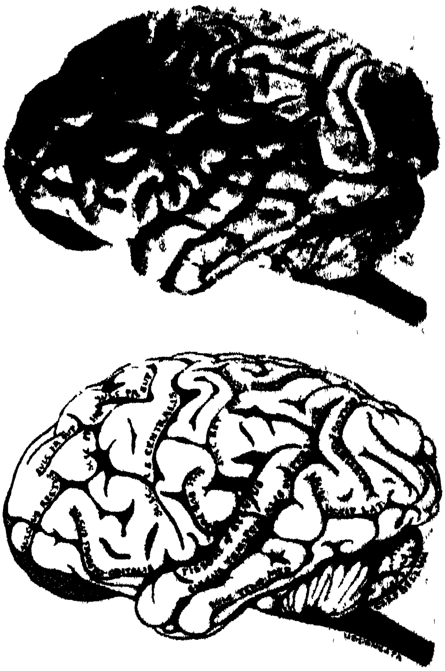


FIG 16. LEFT HEMISPHERE OF THE YOUNG GORILLA, JOHN DANIEL I.

known London shop. The little animal was suffering from influenza and rickets. Miss Cunningham took this infant gorilla into her house and nursed him through his sickness. In the next three years he reached the weight of 112 pounds and attained the height of 3 feet 4½ inches. Meanwhile he acquired many of the adjustments necessary to fit him as an interesting if wholly unusual member of the household. Miss Cunningham has given us an excellent account of his life and habits (Fig. 15). John Daniel became gentle and affectionate in response to the tender care he received. At the end of six weeks he was thoroughly housebroken and allowed the freedom of the house. Generally speaking, he was not a thief. He manifested average honesty; but when it came to food, he always preferred to steal it. While growing up he showed a fondness for friends and strangers, especially when they visited him in his home. He always took afternoon tea with the family and liked his demi-tasse of coffee after dinner. The family's estimate of him was generally high. Incidentally John Daniel had a very good opinion of himself. He was quite well poised and self-contained. Nothing seemed to ruffle him. He appeared to believe that his own estimate of himself was shared by others and seemed confident that every one was delighted to see him. After his death Miss Cunningham secured another young gorilla, which she called John Daniel the Second. These two great apes resembled each other closely in their emotional reactions and in their responses to training. John the Second was, perhaps, a less likable individual and had a disposition more in keeping with the ancient repute of gorillas (Fig. 16).

Other young animals of this species have been studied in captivity. One of them, Congo the Second, has been the basis of the most careful and scientific study thus far made on this animal. In his book called "The Mind of a Gorilla" Professor Yerkes has given us another of his brilliant works on animal behavior. All his observations are illuminating and helpful in understanding the brain of this great troglodyte.

The gorilla's brain is larger and weighs more than that of any other anthropoid apes. In many other respects it is nearest to the brain of man. The Rolandic fissure forms the boundary of a well-defined frontal lobe. All the other fissures and lobes are more prominent and slightly more complexly convoluted than in the chimpanzee. If any comparative estimation can be justified at the present time it is that the gorilla's brain appears to be the most advanced of the apes and is, in fact, almost human.

(*To be concluded*)

PLANETARIUM OPERATION

By JAMES STOKLEY

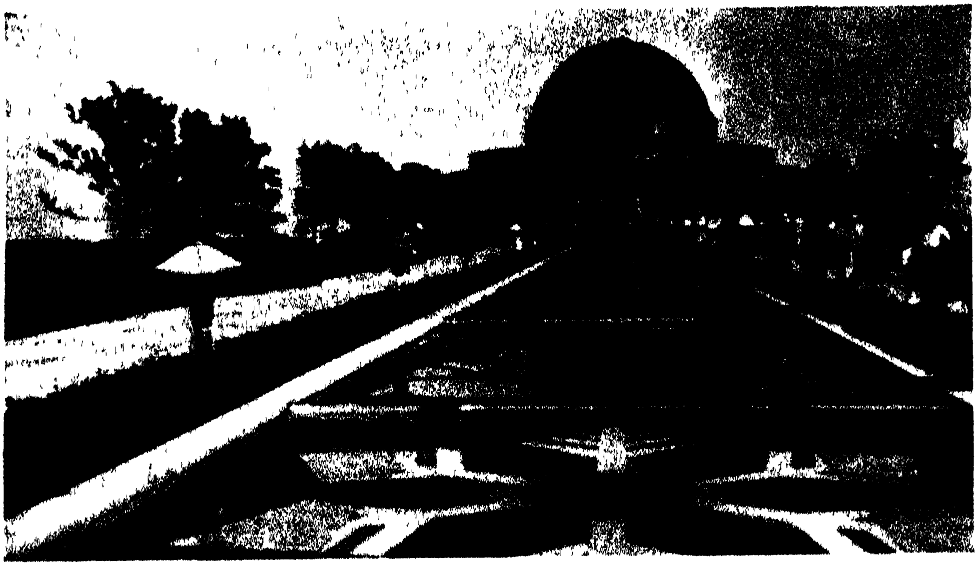
DIRECTOR OF THE FELS PLANETARIUM OF THE FRANKLIN INSTITUTE, PHILADELPHIA

FOUR planetaria of the projection type developed by Carl Zeiss, Jena, are now in operation in the United States, nineteen are in operation in Europe, another is being built in Paris, and one opened earlier this year in Japan This remarkable instrument, which has been fully described in earlier papers by the author and others, is therefore firmly established as an education feature. In several other American and Canadian cities projects to install them are under way. We of the Fels Planetarium have been in touch with many of these and are always glad to be of any possible help and to give suggestions gained from the four years in which we have been in operation.

The first problem to confront the prospective operators of a planetarium is that of the initial cost and then that of the income to maintain it. The cost will, of course, vary considerably, depending upon how elaborate an institution is desired. Erected and delivered in the United States, duty-free, the instrument costs 315,000 RM, or about $127,500 at the current rate of exchange There are a few accessories that seem to be essential, and $500,000 seems a modest figure for the entire institution. This does not include real estate, which could generally be obtained at little or no cost. Not including interest and depreciation, the operating expenses would be about $25,000 per year. If this is to be provided from endowment, another $600,000 would be needed, so that a total outlay of $1,100,000 would provide for a planetarium and keep it running, without any dependence on admission charges.

No planetarium in this country, nor, as far as I know, abroad, is in this happy position of being maintained by an endowment We are all more or less dependent upon admissions. The Adler Planetarium, in Chicago, has free demonstrations three days a week, and this is the only one in the United States to which adults are ever admitted without paying. At the Griffith Planetarium in Los Angeles, the Hayden Planetarium in New York and the Fels Planetarium, the only free admissions are to school children. The usual admission fee is 25 cents, though this varies from 15 cents, which is a special rate that is given in Philadelphia to school groups from outside the city limits, to 60 cents, charged at the Hayden Planetarium for reserved seats at evening demonstrations. Consequently, an attendance of about 100,000 paid admissions per year will be necessary.

Of course, the novelty of a planetarium at first attracts many people, and the attendance is high, then it levels off, subject, perhaps, to occasional stimulation by large conventions or expositions held in the city. In a very few cities, such as New York, there is a large transient population from which to draw—people visit it with the intention of "going places" and this affords a particularly favorable class. Most cities, like Philadelphia, however, are dependent more completely upon the local inhabitants. By comparing the population of the metropolitan area of the four present planetarium cities, it is possible to obtain some idea of what the attendance might be at first in other places.



THE ADLER PLANETARIUM AND ASTRONOMICAL MUSEUM, CHICAGO.
THIS WAS THE FIRST PLANETARIUM IN THE UNITED STATES. IT IS SHOWN HERE WITH THE APPROACH BUILT FOR IT AT THE TIME OF THE CENTURY OF PROGRESS EXPOSITION.

The population of Chicago and suburbs is given by the World Almanac as 4,364,000, and the paid attendance at the Adler Planetarium during the first year was 5.3 per cent. of this, or 230,943. Philadelphia's metropolitan population is 2,847,000 and the paid attendance at the Planetarium during the first year, ending November 6, 1934, was 192,000, or 6.7 per cent

During the first year of operation, ending on May 14, 1936, the paid attendance at the Los Angeles planetarium was 252,706, about 11 per cent. of the metropolitan population of 2,318,000. That this represents mainly the transient population is shown by the fact that the maxima of attendance came at the very times of most visitors to the city. Incidentally, Dr. Alter, director, has pointed out that the attendance curve is very similar to that of the Huntington Library, so an institution of this type in a city might afford a good index of the prospects of a planetarium.

The first year of the Hayden Planetarium ended on October 2. 1936, with 691,136 persons having paid admission during that time This is a record exceeded only by the Adler Planetarium during the first year of the Century of Progress exposition. It is 6.3 per cent. of the total of 11,000,000 people in New York's metropolitan area. Judging by these data, it therefore seems that any progressive city could count on a paid attendance during the first year of at least 5 per cent. of the combined population of the urban and suburban areas.

How much will the attendance drop during ensuing years? In Table I is given, through the courtesy of Dr. Philip Fox, director of the Adler Planetarium and Astronomical Museum, their attendance record for six years of operation. Because of adverse effects of the Century of Progress before and following it on account of construction and demolition, and the very favorable effect that it had while open, these can hardly

TABLE I

ATTENDANCE AND RECEIPTS AT THE ADLER PLANETARIUM AND ASTRONOMICAL MUSEUM

Year	Total[1]	Paid	Receipts
1st (1930–31) .	731,108	230,943	$ 57,848.25
2nd (1931–32) .	511,064	146,438	36,554 00
3rd (1932 33)[2]..	290,265	64,080	16,042 75
4th (1933–34)[3]..	925,156	852,070	212,843 00
5th (1934–35)[3]..	469,377	411,718	102,870 28
6th (1935–36)[2]..	222,876	35,602	9,022.25
7th (1936–37)[2]..	256,018	42,068	10,517 00
Totals ..	**3,405,864**	**1,782,919**	**$445,697.53**

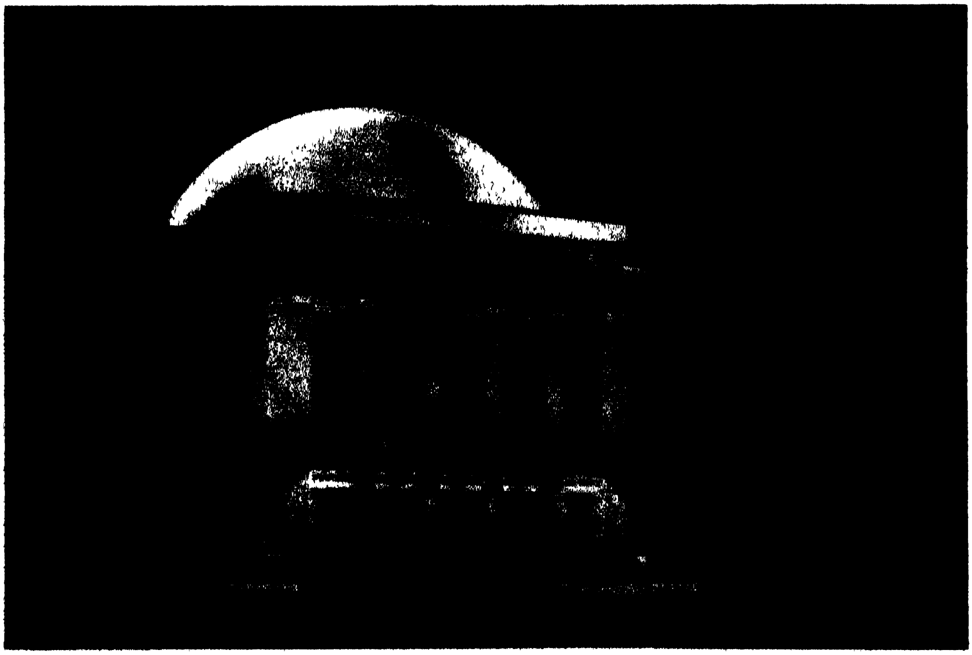
[1] Including visitors to the museum who did not attend a demonstration of the planetarium instrument

[2] Dr Fox states that "construction previous to, and demolition following the Century of Progress, with torn up approach to the Planetarium, greatly affected attendance during 1932 and since the fair"

[3] 1933 and 1934 Century of Progress periods included, during which there were no free admissions

be considered typical. Table II, however, presents a comparison of these figures for the pre-fair period with those of Philadelphia over the first three years, together with the records of the first two years in Los Angeles and the first in New York. It will be noted that in the second year of the Fels Planetarium paid attendance dropped 41.6 per cent. from the first year; but that the third dropped only 14.5 per cent from the second. This seems to indicate that a level of attendance is being reached.

Considering these data, it seems that in general a city of less than 1,500,000 inhabitants in its metropolitan area would be unable to support a planetarium by admissions alone. If some local group, the school board, for instance, could contribute part of the expenses, any of the six cities not already provided, and with at least a million inhabitants to draw upon, should certainly be able to support one. These are: Boston, Cleveland, De-



THE HAYDEN PLANETARIUM,

PART OF THE AMERICAN MUSEUM OF NATURAL HISTORY, IN NEW YORK, WAS THE FOURTH IN THE UNITED STATES. THE BUILDING WAS ERECTED WITH FUNDS BORROWED FROM THE RECONSTRUCTION FINANCE CORPORATION.

TABLE II

COMPARISON OF ATTENDANCE AT AMERICAN PLANETARIA

Name and date opened	Total*			Paid				
	1st year	2nd year	3rd year	1st year	2nd year	Decline Per cent	3rd year	Decline Per cent
Adler 1930 May 12	731,108	511,064	290,265	230,943	146,438	36 4	64,080	56.1
Fels 1933 Nov 6	281,975	167,364	124,480	191,883	112,265	41 6	96,018	14.5
Griffith 1935 May 15	696,566	506,099		252,706	195,251	22 7		
Hayden 1935 Oct 3	856,236			691,136				

* In the case both of the Adler and Griffith Planetaria, the figures for the total include visitors to the museum, who did not in many instances visit the planetarium itself. The total attendance at the Fels Planetarium and the Franklin Institute Museum during the first year (ending Nov 5, 1934) was 548,987

troit, Pittsburgh,[1] St. Louis and San Francisco. Then there are individual factors that would change the conditions in certain places. Washington, D. C , for example, is listed with a metropolitan population of 621,000, but because of the transient population, as well as of the proximity of Baltimore, with 949,000, it could undoubtedly support a planetarium with success.

The Hayden Planetarium was built with funds from the Reconstruction Finance Corporation, and is to be repaid to the government over a period of years This has led many other cities to consider the possibility of doing likewise, or at least of borrowing the money and amortizing the debt, as well as paying operating expenses, out of the income. To do this in, let us say, 30 years, would necessitate at least double the income assumed above, and, other things equal, double the population. Using this as a criterion, Detroit seems to be the only city without a planetarium now that could possibly erect one in this manner.

But after all, why should we expect such an institution to pay for itself, any more than we expect a cash return from any of our museums or from our public schools? In modern cities, the glare and dust make the starry skies a much less conspicuous part of our environment than they were a century ago, and people forget about them. Yet how can a person be really educated unless he has at least a passing acquaintance with the universe in which we are living? Here at last the projection planetarium provides a means of showing the stars, in a manner that is even more convenient than the real sky itself, because it is not affected by bad weather or daylight, and the motions can be accelerated to show the changes of many years or even centuries in but a few minutes. The intangible benefits from a planetarium are certainly far greater than those from many things for which municipalities and other political subdivisions have spent many more dollars of the taxpayer's money.

A group erecting a new planetarium should certainly draw upon the experience of those already in operation. The type of projection dome is one thing that must be decided. The Adler Planetarium, like those in Europe, has one of stretched cloth. This has the disadvantage of getting dirty and requiring renewal, as it can hardly be cleaned in place. The Griffith Planetarium has a dome of acoustic tile, which is an improvement. The dome of the Fels Planetarium is of painted stainless steel sheets, bent to the proper curvature and perforated to prevent echoes Its diameter is 20 meters In the opinion of unprejudiced observers, this is the best planetarium dome in existence. Its success induced the builders of the Hayden Planetarium to adopt a somewhat similar construction

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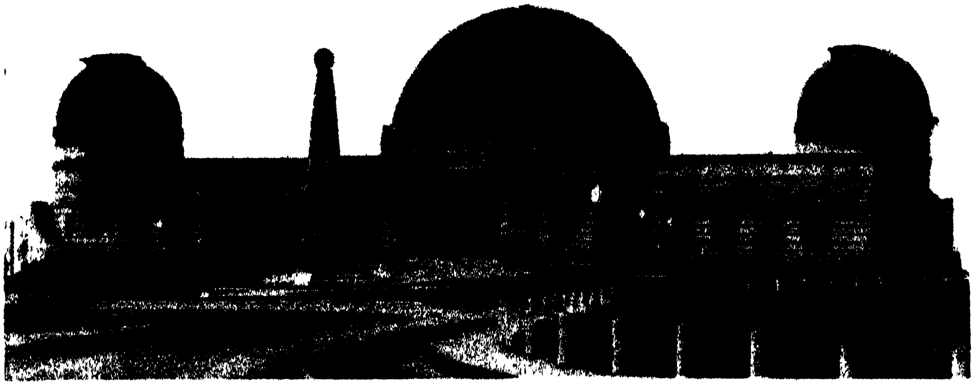
[1] While this article was in press plans were announced for a fifth American planetarium, to be placed in Pittsburgh. The instrument has been ordered, and actual work started. The building, including a technological museum, is being erected by the Buhl Foundation, which will also contribute toward the operating expenses.

In the Fels Planetarium, the dome is on the ground floor and is completely surrounded by other parts of the building. The space around the projection dome is very irregular and this contributes to the excellent acoustics, because there is little chance for sound to be focussed to cause an echo. In addition, a large proportion of the surrounding wall is covered with acoustic absorbing material. If it is desired to have an outer dome, this should not be concentric with the inner one, but should be of considerably longer radius of curvature With a concentric outer dome, echoes are almost unavoidable, even if it is entirely lined with absorbing pads. These may absorb 98 per cent. of the incident sound, but the remaining 2 per cent., when concentrated from a large area, is sufficient to cause an objectionable echo.

Because of the fact that no windows or doors can be opened while lectures are in progress, ventilating equipment is necessary, and this should be of modern type, preferably to condition the air in winter and summer Special pains must be taken to prevent any noise from the motors or fans being heard in the chamber, either through the ducts or the walls. Extra lighting should be provided. At the times of demonstration, all the illumination comes from the instrument, but the other lights are needed for cleaning the room, when the instrument is completely turned off; or when the chamber is used for another meeting.

The projection and sound equipment is another important accessory. Motion pictures as well as lantern slides can be used to advantage, and the projector must generally be in a fireproof booth, in which the ports should be glazed to keep the sound of the machines out of the chamber.



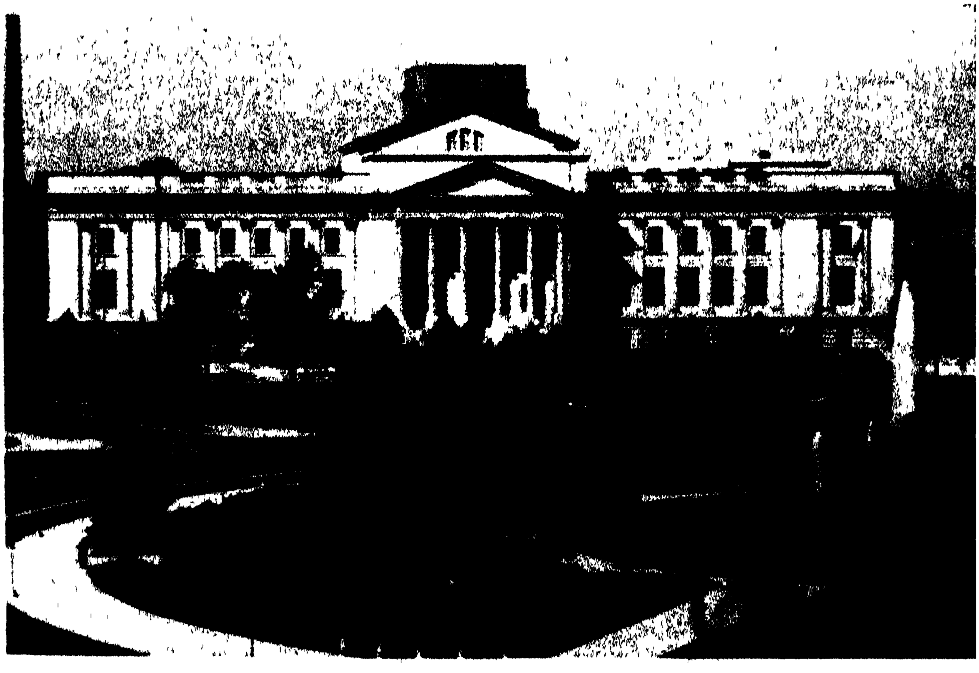
THE GRIFFITH OBSERVATORY IN LOS ANGELES

SHOWING THE ASTRONOMERS MONUMENT, IN FRONT OF THE MAIN ENTRANCE. THE PLANETARIUM IS UNDER THE LARGE CENTER DOME. THE SMALLER ONE TO THE LEFT CONTAINS A TWELVE-INCH TELESCOPE FOR THE USE OF VISITORS, WHILE THE ONE TO THE RIGHT HOLDS A COELOSTAT FOR REFLECTING SUNLIGHT BELOW.

Sound motion pictures will seldom be needed, though complete equipment for them can easily be installed, as many of the amplifiers will be provided for in the equipment for furnishing music. This is very desirable, both to entertain the visitors while waiting for the lecture to start, and also to give special effects by introducing it at appropriate times during lectures.

It is also easy to install a microphone that can be connected with the loud speakers, so that the voice of the lecturer may be reinforced if necessary. However, the acoustics of a planetarium ought to be so good that no competent lecturer should need such aid. A microphone can be used for two other very desirable functions, one of which is to supply deaf sets for the use of persons with defective hearing. The other is to operate a loud speaker in the projection booth so that the operator can follow the lecture. The best place for the loud speakers is at the top of the dome, for then their direction is least apparent to the audience, and the entire chamber seems to be permeated with music The system should be capable of sufficient power to produce special sound effects when wanted.

Several institutions having planetaria, including the Franklin Institute, gave consideration to placing the instrument on an elevator, in the manner of the orchestra in a motion picture theater. Because of the expense, however, the decision has always been against it We have often regretted that this was not done, for it would be most effective to have the audience enter the room and see nothing in the center, then to have the instrument appear at the start. Or the auxiliary lighting might be used when the audience entered, and the instru-



THE BENJAMIN FRANKLIN MEMORIAL AND THE FRANKLIN INSTITUTE IN PHILADELPHIA. AN IMPORTANT PART OF THE ASTRONOMICAL SECTION OF THIS GREAT TECHNOLOGICAL MUSEUM IS THE FELS PLANETARIUM, WHICH WAS THE SECOND IN THE UNITED STATES.

ment brought into place after the chamber was dark. This would greatly increase the realism, for it would not be apparent what was producing the stars. If the hole into which the instrument descended were to be covered, it would be easy to arrange the room for another meeting. At present most planetaria can be moved on tracks to one side for this purpose, though at the Franklin Institute, with another lecture hall in the building, no other meeting has ever been held in the planetarium chamber.

On several occasions, when presenting special lectures, we have erected a small stage at one side of the room on which to show certain exhibits. If such a stage were installed at the time of erection of the building, this would be much simpler. It should be below the horizon line of the dome, and might be about ten feet in width.

The chief need for a planetarium when once established is a steady attendance, and unless this is achieved, the institution will be a failure. School groups can be brought to special demonstrations, whether the students want to come or not, but this provides no excuse for not making them as interesting and attractive to the audience as any to paid attendance. The children can be splendid missionaries, spreading word at home and making their parents want to see this remarkable device.

The visitors must be so interested that they will come again and again. In many of the German planetaria it has been the practice to give the same demonstration for a long period of time and to change it only after the attendance had dropped to a low figure. The American practice, on the other hand, has been to give new lectures every month. So many things can be demonstrated that they can not possibly all be shown at one performance. There are perhaps twenty different topics that can be treated. We, for example, devote two months a year to the constellation figures, pointing them out and telling some of the mythological stories associated with them. These are given in January and July, for the winter and summer evening skies, respectively, and are the simplest lectures presented. Others, such as one on "Time and Navigation" or another on "The Calendar," are necessarily somewhat more technical in their content, though, with the aid of the planetarium, the explanations can be kept simple enough for any one of normal intelligence to understand. Of course, it is assumed that the members of the audience will pay at least reasonable attention to the lecturer. In between these in technicality are such demonstrations as "Comets and Meteors," "Skies at the North Pole," "The Southern Skies," "The Planets and their Motions," etc.

In a city like New York, where there is such a large transient population, probably most of the planetarium visitors come only once, and it will be some time before the lecturer can assume that a large proportion of his audience has attended before. In Philadelphia, however, we find that from one third to a half of each audience is made up of what might be called "repeaters." Many persons have come three or four times, a few have attended practically every lecture since our opening, and one gentleman has come at least fifty times!

An effort is made to encourage people to come back again and again, and for this reason we try to make the lectures sufficiently different to attract them. Thus, we no longer give a detailed description of the instrument and its operation, as we did at first, but those who wish to know about its technical features may get information by asking questions of the lecturer after the demonstration. However, there are a few things that we include in every lecture. With one or two exceptions, each starts, after a preliminary period of five to ten minutes, during which the lights are being dimmed to get the eyes of the audience dark-adapted, with the sunset of the present day. This gives the opportunity to point out the stars currently visible in the evening. Then, after passing through the night, the lecturer goes on to the particular topic under discussion that month. Each lecture is thus complete in itself, and a person who comes for the first time will hear a complete story.

However, there is necessarily enough similarity about such lectures to discourage many persons from coming more than four or five times at the most, and we believe that a partial answer to this problem is with what we have termed special lectures. Each December since we opened, we have set the instrument back to the year 6 B.C., and have shown the conjunction of three bright planets which, according to Kepler's suggestion, was the original "star of Bethlehem." In 1935 and 1936 we gave this again, but added a special program of music and lighting effects, to give it something of an emotional as well as a scientific appeal The response from the public was extremely gratifying.

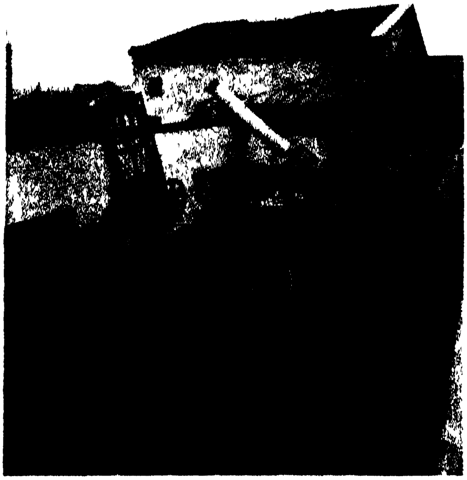
PART OF THE DOME OF THE FELS PLANETARIUM DURING CONSTRUCTION.

THE DOME WAS MADE OF PLATES OF STAINLESS STEEL, PERFORATED WITH SMALL HOLES IN ORDER TO BE PERVIOUS TO SOUND. ROCK WOOL PADDING ON THE WALLS IN BACK ABSORBS THE SOUND WAVES, AND PREVENTS ECHOES. THIS TYPE OF DOME, FIRST USED IN PHILADELPHIA, WAS ALSO EMPLOYED IN THE HAYDEN PLANETARIUM.

Another special lecture, given during April, 1936, was called "How Will the World End?" In this we discussed theories that have been proposed by eminent scientists as to the ultimate fate of the Earth, and also introduced lighting effects and a musical background This involved no departure from scientific accuracy, because we carefully pointed out that they were all merely theoretical possibilities and that other factors might prevent any one of them from coming to pass.

The late Dr. Oskar von Miller, founder of the Deutsches Museum, where the first planetarium was erected, once said that a planetarium by itself was like a motion picture theater with one film, and I think this is perfectly true. Important though the planetarium is in teaching the elements of astronomy, it does not tell the whole story, but should be supplemented whenever possible with observations of the actual sky. At least a small observatory should be associated with every planetarium. This need not increase the cost of the entire project more than a few per cent., for an extremely large instrument is not needed. In fact, a central city location, which is the best for the planetarium, to make it convenient of access, is one of the poorest locations for an observatory. An 8-inch or 10-inch refracting telescope, a 15-inch or 20-inch reflector, will do excellent work in showing the visitor the typical objects in the heavens. If a telescope is installed, the first thought might be to place over it the usual observatory dome. For a research instrument the dome is highly desirable; for a museum it might be partly justified from the point of view of showmanship, for the public does expect an observatory to be covered with a dome. But from the standpoint of maximum value to the visitor, a sliding roof, with which the entire sky is exposed, is much to be preferred With a dome, the sky is visible through a narrow slit, the visitor's view of the vicinity of the object at which he looks is greatly restricted. The sliding roof, on the other hand, allows him to orient himself with respect to familiar star groups in other parts of the sky. The next night, when he is looking at the skies from his home he can tell just where the planet or nebula is at which he gazed through the telescope.

An observatory also offers an excellent opportunity for the small museum, in a community that can not support a planetarium, to take an interest in astronomy. In its establishment, if at all possible, the cooperation of local amateur astronomers should be secured. Recent years have seen a great revival in interest in astronomy, and there are many local astronomical societies throughout the country whose members are generally only too glad to help. Even when there is no society, a few interested persons could doubtless be found who would form the nucleus for such an organization. Closely related to such activity is the work of the amateur telescope makers. Since 1924 thousands of these instruments have been made, often by individuals working in the cellars of their homes. Others have worked in groups at some central, well-equipped headquarters, several of which have been established in connection with museums. After such amateurs become sufficiently expert, they might even be able to construct a telescope for the museum.



THE OBSERVATORY OF THE FRANKLIN INSTITUTE.

IN THE FOREGROUND IS A 24-INCH REFLECTING TELESCOPE BY FECKER, AND IN THE REAR A 10-INCH REFRACTOR, BY ZEISS. THE SLIDING ROOF, OPERATED BY AN ELECTRIC MOTOR, EXPOSES TO THE VIEW OF VISITORS THE ENTIRE SKY, INSTEAD OF THE LIMITED AREA SEEN THROUGH THE SLIT OF THE USUAL DOME.

Far less expensive, even, than a small telescope is a good series of astronomical photographs. These can best be displayed as transparencies, which can be obtained from most of the large observatories. And now they can be supplemented with motion pictures. The McMath-Hulbert Observatory, an amateur institution now part of the University of Michigan, has specialized in astronomical films, and already has several excellent subjects available. These include sunrise and sunset on the Moon, Jupiter and the motion of its satellites, the solar eclipse of 1932 and disturbances on the Sun. Like the lapse-time cinema pictures of growing plants, the motion is accelerated, and it is possible to see in a few minutes what would have required many hours, on the same night, of watching through a telescope. We have used these films to advantage both in connection with the planetarium demonstration and as separate "shows" in our astronomical exhibit hall. They are available in either 16 or 35 millimeters.

For astronomical museum exhibits there are many opportunities. Beautiful though the effect of the planetarium may be, it is a fact that it obtains its results by a geocentric mechanism and does not give the visitors a proper appreciation of the way that the planets move around the Sun Consequently some sort of orrery should be used in conjunction with it This might be either a small one, like that supplied by Michael Sendtner, of Munich, which we have in the entrance lobby, or a large one occupying a room nearly as big as the planetarium chamber itself, like the one at the Hayden Planetarium.

Many other working models can be prepared, to show an eclipsing binary star, one in which a bright and a dark component revolve around each other, the dark one periodically eclipsing the brighter. A model of a transit instrument on a turning globe, to show how time is determined from the stars; a Foucault pendulum, showing the rotation of the earth, and a model to show its action; a demonstration of the action of mirrors and lenses in forming telescopic images—these are but a few of the interesting exhibits that can be made, at relatively small cost Any museum can have some department representative of astronomy if the authorities wish to do so.

THE ALPINE PASSES IN NATURE AND HISTORY

By Dr. **WALTER WOODBURN HYDE**

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MY first Alpine walk was over the Simplon Pass, which I crossed in July, 1899, from Iselle di Trasquera at the Italian base to Brigue on the Upper Rhone in Switzerland. While it is not one of the lofty passes, such as the Great St. Bernard or Stelvio, for it is only 6,582 feet high, it is one of the most beautiful in the Alps Since that time I have walked over most of the major passes which lead across the Great Divide from France, Switzerland and Austria into Italy, and some of them twice, but the impression then made upon me by the Simplon Pass still lingers vividly in my memory

In those days the great railway tunnel beneath the highway was under construction, for it was not opened to traffic till seven years later. The only way, therefore, to reach Brigue was over the pass on foot or in a diligence. While one can now—as I have since done—ride comfortably through the tunnel, a distance of nearly thirteen miles, in less than thirty minutes, the foot-journey over the top of the pass still remains a long day's walk of thirty miles.

The highway, built by order of Napoleon between 1801 and 1807, is a remarkable feat of engineering. Between Domo d'Ossola on the Tosa, twenty-seven miles below Iselle in Italy, and Brigue there are 613 bridges, 8 avalanche galleries and 20 refuges. Above Gondo, the first Swiss village on the ascent, it skirts the Gondo Gorge to Gabi, four miles beyond, one of the wildest defiles in the Alps. At one point here Napoleon's engineers had to tunnel a granite cliff whose perpendicular walls rise some 2,000 feet.

The views from the summit of the pass are among the finest in the Alps. From the Bellevue Simplon-Kulm Hotel, which in recent years has relieved the neighboring hospice of extending hospitality to all except indigent travelers, one looks down the descent into Switzerland surrounded by a galaxy of snow-clad peaks rising in gigantic walls on either side, while the view to the north is closed by the Sparrhorn and the loftier Nesthorn to the left and the conical summit of the Eggishorn to the right. Farther down, below the village of Berisal, the valley of the Upper Rhone comes into view, stretching for miles with its green meadows, ribbon-like river and snowy peaks in the distance.

Such mountain excursions I have found the pleasantest feature of a holiday in the "Playground of Europe." Not only do they afford delightful and exhilarating walks along splendid highways, but the novelty, it may be, of passing a night in some lofty inn or monastery. Some of the pass-routes reach altitudes of 8,000 feet or more, the Stelvio in the Central Alps, the highest motor-road in Europe, over 9,000. Its summit has long been provided with a hotel from which one can enjoy superb views down the gentle Italian slope and the almost perpendicular Tyrolean descent to Trafoi with the huge snow-capped Ortler immediately in front, the Oetztal Alps far to the north and the Bernina group to the southeast. Nearby is the Dreisprachenspitze, an eminence on the Pizzo Garibaldi, nearly 300 feet higher, where before the World War when seated on a boulder you could distribute your weight over three frontiers, those of Switzerland, Austria and Italy. You can still cover three linguistic areas —German, Italian and Raeto-Romanic!

It has always aroused my wonder and indignation that the thousands of tourists who visit Switzerland each summer have never learned to avail themselves of such mountain excursions. To almost a man they seem quite content with the lower levels, and to look up at the snowy peaks from such tourist-haunted centers as Geneva, Interlaken and Luzerne. They never dream that the views from the heights are incomparably grander and that many passes are easily reached by foot, and, if one wants more strenuous exercise, that there are plenty of minor passes reached by stony bridle-paths where one can be alone with nature at her best.

I have also found such walks a valuable preparation of heart and muscles for undertaking the climb of some major peak. Now that for reasons all my own I no longer can climb among the rocks and precipices of the Matterhorn nor the snows of Mont Blanc, the easy ascent of the passes has, in a measure, reconciled me to the loss. While the way may be long, every step in the clear atmosphere reveals a constantly changing panorama of ridges and peaks and glimpses into green valleys far below, and makes one rejoice to be alive. And even amid the discomforts of storms the mountain views are grand.

If one be adverse to such exercise he can at least drive over many passes in an autobus, the successor of the horse-drawn diligence of a generation ago, as these in fair weather are open and allow one to view the scenery with ease. But I have found nothing comparable with a foot-traverse and in the last few years I have made many. Thus in the summer of 1927 I crossed eight passes in the Western Alps, in that of 1929 a dozen in the Central Alps ranging from 6,000 to 9,000 feet in height, and in 1931 five more in the Austrian Alps north of the main chain. These latter are lower, but afford exquisite views of distant ridges and meadows gleaming in the sunlight. They are, moreover, known to few tourists.

But to me the greatest attraction of such walks is the knowledge that many of these passes have played important rôles in history from antiquity to our time. Such a story, beginning with the Romans in their expansion northward in the early Empire, covers a period of over two millennia. Further back we may even glimpse a little of their prehistoric use, as disclosed by archeology and historical inference.

Thus neolithic settlements once dotted the entire course of the Brenner in the Eastern Alps, just as villages do to-day. The early use of the Ligurian coast-road along the Riviera from southeastern France to Genoa is attested by myths of Heracles and King Cycnus—the latter in connection with the prehistoric amber-trade southward to the Mediterranean from the North Sea. Similarly, the early use of the Little St. Bernard into the Val d'Aosta is shown by its ancient name *Alpis Graia,* which the Romans, ever bad etymologists, wrongly translated as the "Greek" pass over which they believed that Heracles, the first mortal to cross the Alps, found his way while driving Geryon's oxen from Spain to Greece. Some of the eastern passes, notably the Brenner and Birnbaumerwald, because of their moderate heights, served as gateways through which many folk-wanderings reached Italy from Central and Eastern Europe long before Italy was guilty of Rome. In this way the earliest Indo-European invaders of Italy, the Terramare peoples, must have reached the valley of the Po from the Save and Drave, and ultimately the Danube, bringing with them the rudiments of Italian culture and a speech which was the forerunner of Latin.

And at the end of antiquity it was over these passes in the eastern Alps that many barbarian hordes came from the north in the fifth century to overwhelm the Roman Empire. Thus came the vanguard, the Visigoths under Alaric in 402 and again later to sack Rome in 410—the first time since the Gauls under Brennus had sacked it exactly 800 years before, and an undertaking which even Hannibal had not dared. Radagaisus with his barbarians came in 405 only to meet defeat. And in the middle of that terrible century came Attila the Hun, who boasted that grass never grew again where his horse's hoofs had trod, and destroyed Aquileia at the head of the Adriatic and was kept from sacking the Eternal City once more only through the persuasions of Pope Leo. Later, after Vandals under Gaiseric had reached Italy by sea from Africa and again destroyed Rome, still other Germanic tribes crossed the great mountain barrier, until finally Theodoric the Great with his Ostrogoths came in 489 and founded his Gothic kingdom of Italy, and old Rome was no more.

Thus the ancient history of the Alps, from the advent of the Romans to the foothills and their slow expansion over the summits northward to Rhine and Danube down to the extinction of their mighty Empire is alone full of interest and even romance. Then followed the story of the Alps through the Middle Ages and modern times, when the Alpine passes again became important in the story of Europe. It will, therefore, be profitable to recount a few of the chief events in that long story.

Our real knowledge of the Alps hardly antedates the coming of the Romans in the latter part of the third century B.C., long after Rome had become mistress of Italy. The very first mention of the Alps in European literature is found in the Greek historian Herodotus, who wrote in the middle of the fifth century B.C., but to him Alpis was only a river, a tributary of the Danube. A century later Aristotle called the chain by its earliest name—whether Celtic or Germanic—the "Arcynian Mountains," a name recalling that of the Hercynian Forest, which anciently spread over a great section of South Germany. But we do not meet the name Salpeis till the third century B.C., in the work of a little-known Alexandrian poet.

Curiously we do not yet know with certainty the origin of the name. The Romans naturally connected it with their adjective *albus*, but more probably the name is Celtic for "lofty mountains," as Celtic or Gallic tribes for centuries occupied both slopes, having reached Italy from eastern Switzerland by way of the Brenner some time near the close of the fifth century B.C. Their settlements finally extended from sea to sea, so that throughout Roman times North Italy was known as Cisalpine Gaul Remains of their speech are still found in the Italian foothills.

Two centuries after the unheralded coming of the Celts occurred the most spectacular transit of the Alps in ancient or modern times, that of Hannibal and his elephants over a western pass in the fall of 218 B.C. In fact it was his crossing which first aroused the Romans to an active interest in their northern barrier, and it was his traverse far more than his supreme military genius which has left so indelible a memory on all posterity since. Thus the identification of his pass has been the subject of endless discussion in our time, when all sorts of books, both technical and semi-romantic, have been written on this theme from the historical, topographical, military, meteorological and economic points of view. And we feel certain that the vexed question will continue to intrigue investigators, since the data available are insufficient to render a decision agreeable to all.

Shall we ever know Hannibal's pass? All we know for certain is that in marching from the Rhone he must have crossed a western one. Consequently, every pass west of the Simplon has had its defender—the *Encyclopedia Americana* even giving the glory to the latter itself, the most unlikely of all. We might quote the words of Douglass Freshfield, the sponsor of the Col de l'Argentière route: "For until a suit of Punic armor or an elephant's skeleton has been brought to light, the Alpine adventures of Hannibal must, I fear, continue as in Juvenal's day to interest boys and perplex schoolmasters." As an humble one of the latter I would reply that even such evidence would not be conclusive, since it might equally fit the pass used by Hasdrubal when, eleven years later, he came to the aid of his more illustrious brother—and that pass is shrouded in even greater mystery.

While the traverse of an Alpine pass by an army has ever been regarded as a major military exploit, that of Hannibal is remarkable not because of his "tanks" of that day, I mean his elephants, nor the hostility of the mountaineers, nor lack of food and fodder, nor even of a road, but merely because of the lateness of the season, at the end of October, when snow and cold on any pass are a menace. A few weeks earlier would have robbed the exploit of much of its glamor, as various Celtic tribes had crossed the mountains long before with their women, children and animals, and seemingly without difficulty.

To-day, after two centuries of learned wrangling, the route of the Carthaginian seems to be narrowed chiefly to one of three passes. Livy's account, written two hundred years after the event by the most imaginative of Roman historians but by one who knew nothing of the terrain involved, has Hannibal ascend the Durance from the Rhone, which would, if there were not grave difficulties in the way, certainly lead him over the Mt. Genèvre. The more prosaic Greek historian, Polybius, who was born during the Hannibalic War, had lived in Rome where he "questioned persons actually engaged in the events" and had in person "gone over the Alpine pass," seems to have him ascend the Isère from near Valence on the Rhone, which would as certainly lead him over the Little St. Bernard or some nearby pass.

Both these routes have had their henchmen—the Mt. Genèvre from Gibbon in the eighteenth century to W. A. B. Coolidge, the latter a practical mountaineer who advocated it only after crossing every possible pass; the Little St. Bernard from Bréval in the eighteenth century, through Niebuhr, Mommsen and Kiepert in the nineteenth, and down to Lenschau and others in the twentieth.

Unfortunately neither of these routes has an eminence from which Hannibal could have shown the plains of Italy to his band of "emaciated scarecrows," as both Livy and Polybius have him do. For this reason recently a by-pass, the Col Clapier leading from Bramans in France to Susa on the Italian descent of the Mt. Genèvre, which does fulfil this condition, has been advocated especially by French military critics of Hannibal. However, it is nearly a thousand feet higher than the Little St. Bernard and two thousand higher than the Mt. Genèvre, and besides its Italian descent for some 4,000 feet from the summit is by a zigzag rocky stairway down which it seems impossible that his elephants could have gone. It may, therefore, be better to regard the incident of the view as a fiction of Polybius copied by Livy, and to accept the Little St. Bernard as the logical route for the world's greatest commander to have followed.

Early in the next century, if not sooner, the Romans were first attracted to the foothills by the mineral wealth of the Celts, especially the gold of the Salassi in the Val d'Aosta and, later, the iron of the Taurisci in the Tyrol north of the Eastern Alps. Thus here, as later in Gaul and elsewhere, Roman merchants preceded Roman soldiers. But the

legions were sure to follow, for soon the Romans came to repel invaders.

The first of these invaders were the Cimbri and their kinsmen the Teutones, the earliest of the barbarian hordes from the north who came in historic times in search of a southern home. In their long trek from Jutland on the North Sea southward they arrived in Noricum (Austria) with the intention of reaching the Po valley over the Eastern Alps. In 113 B.C. a Roman army sent north to meet them was defeated beyond the Alps, but fortunately the invaders did not then proceed further south, but soon marched westward into Gaul. Here in the next few years they defeated three more Roman armies and then crossed into Spain. Later they returned to Gaul, and the vast horde divided; the Teutones tried to enter Italy from the northwest only to be destroyed by the Roman consul Marius in 102 B.C. on the Rhone above Marseilles, while the Cimbri on reaching Italy from the northwest were annihilated the next year by Marius and his colleague near Vercelli. It was their German kin who, over five centuries later, as already mentioned, exacted a terrible vengeance, when they crossed the Alps in successive waves and overwhelmed Italy and the Empire.

Finally the Romans came as conquerors and administrators of the Alpine tribes and areas further north. But it was not till Caesar's Gallic wars—still the perplexity of school boys—that Rome felt the need of subduing the mountaineers in order to control the pass-routes into Gaul and Helvetia. Caesar's plans, cut short by his assassination in 44 B.C., were carried out by his grand nephew, known to us as Augustus, the founder of the Roman Empire. In a desultory war begun around 25 B.C., but whose major operations were completed by the emperor's stepsons, Tiberius and Drusus, in 16–14 B.C., the entire chain became a part of the Roman state.

We need mention only one incident in that war, the subjugation by the Roman commander Varro of the brave Salassi who had long been settled in the beautiful Val d'Aosta just under the Alps. For the incident is typical of the severity shown by Rome in building her empire. Many ancient historians have told it, but I quote a brief paragraph from the later Cassius Dio, who lived in the third century: "After forcing them to come to terms, Varro demanded a certain sum of money, as if he was going to impose no other punishment; then sending soldiers everywhere ostensibly to collect the money, he arrested those who were of military age and sold them on the understanding that none of them should be liberated within twenty years." Strabo, the Greek geographer who lived at Rome near the time, tells us that 36,000 men survived, 8,000 of whom, capable of bearing arms, were sold, and thus "peace was kept as far as the highest parts of the passes."

Augustus's victory over the mountain tribes was commemorated by a trophy in the form of a three-storied tower whose ruins—restored only in 1934—still overlook the blue waters of the Mediterranean at La Turbie (the name is a corruption of Latin Tropaeum) near the summit of the Roman coast-road above Monaco, now a part of Napoleon's *Grande Corniche.* Its weatherbeaten inscription names forty-eight tribes then subjugated, while eight others are known from a smaller trophy set up at Susa on the Mt. Genèvre Route. Augustus further boasts on the famous *Monumentum Ancyranum,* lettered in Greek and Latin on the walls of a ruined temple at Angora in Anatolia, now the capital of the Turkish Republic, that "the war brought injury to none." Yet he had caused thousands to be slain and thousands more to be driven into slavery, all because they had fought the good fight of freedom.

By the close of the war the founder of

the Empire held both sides of the Alps, and he and his successors erected provinces to the north, expanding Roman power eventually from the North to the Black Seas. Only one monarch since, Charlemagne (768–814), has controlled the entire chain, for not even Napoleon gained all the eastern section. To-day the Alps are shared by six nations—Italians, French, Swiss, Germans, Austrians and Jugo-Slavs.

The cultural activity thus started by Augustus was even more remarkable than the conquest—the gradual Romanization of a vast area, a process which continued to near the close of the empire. Yet more, for that concerns ancient history only; for there was started a movement which lasted on through the medieval period down to the fifteenth century, during which the basis of the states of modern Europe was being laid. This was Augustus's unwitting gift to the modern world.

The conduits of this cultural movement were the Alpine roads which Augustus and his successors built to connect Italy with the north. Along these highways in the valleys below flourishing towns arose. To-day most of the important towns as far north as the Rhine and Danube are on Roman sites. In Switzerland alone nearly every large town is on a Roman or Celtic base.

But many of these towns, important in antiquity, have had a different history. Thus Concordia, Altinum and Aquileia in Northeast Italy, the starting places of roads over the Alps, are now mere fishing hamlets. North of the Alps Carnuntum on the Danube, certainly one of the oldest towns in Europe, in prehistoric times being in part control of the Baltic amber-trade, is now a heap of ruins, while Vienna just to the west, once a Roman camp, famed as the spot where Rome's greatest emperor, Marcus Aurelius the philosopher on the throne, died, is now a great metropolis. Sirmium on the Save, one of the four proud capitals of the empire in Diocletian's tetrarchy, is now only the wretched hamlet of Mitrovica in Jugo-Slavia, so named from its cloister of St. Demetrius.

Curiously the Romans from the time of Augustus onward instituted no new routes across the Alps, but were content to improve the ancient trails long before used by Celts and their prehistoric predecessors In all Augustus built some eight roads along these ancient trails; along the Riviera from Genoa west; over the Mt Genèvre, a restoration by his prefect Cottius of an older road built in 77 B C by Pompey the Great; the Little St. Bernard, similarly a restoration of the Gracchan road built in 122 B.C., and so the oldest in the Alps; the Brenner from Verona as far as Trent; the Ploecken route from Aquileia to Trent; the Birnbaumerwald road from Aquileia to Oberlaibach on the Save, later extended as the "Pannonian Highway" to Carnuntum on the Danube; and probably those over the Maloja and Julier connecting the Val Bregaglia in Italy and Coire in the Engadine.

Later emperors repaved these roads or built anew over other ancient trails. Thus Claudius in the first century constructed a road from Venetia through the Valsugana to the Brenner and beyond over the Reschen-Scheideck and Fern Passes to the Danube, and another over the Great St. Bernard from Aosta to Martigny on the Upper Rhone. The Severi between 195 and 215 built the first military road across the Brenner and Scharntz Passes from Trent to Innsbruck and on to Augsburg in Germany.

There are remains of these Roman roads all over the Alps where they have not been covered by modern turnpikes. In the Austrian Alps especially I have frequently seen the sign *Roemer Strasse* near the present highways. There are inscriptions on rock-walls and countless milestones. There are ruins of refuges, notably a large one 216 by 60 feet, dating from the Later Empire, on the summit of the Little St. Bernard, discovered in 1837 by a party of English tourists, and another still larger, 200 feet square, found more recently three quarters of a mile beyond. A ruined *mansio* has also been found on the summit of the Great St. Bernard along with the remains of a temple of Jupiter—the latter the highest in the Roman Empire. There are many rock-cuttings against wind and snow, one, 200 feet long and 10 feet wide, being visible on the Great St. Bernard.

Stretches of ancient pavement, often with the ruts of chariots and carts cut deep into the stones, are numerous everywhere. Recently I followed two such above Radstadt on the northern side of the Radstaedter-Tauern Pass—one, now high above the modern road along the river, the other a mile long nearer the summit. Perhaps the best preserved remains are those between Haidenschaft and Oberlaibach on the Birnbaumerwald route, but certainly the most imposing are those just outside the hamlet of Altino, the beginning of the Via Claudia Augusta—now locally known as Agozzo. Here the pavement is twenty meters broad, but it gradually narrows to six, and in the foothills beyond to less.

Excellent examples of wheel-ruts are visible, five to six feet apart, on the top of the Julier. Above Tweng on the southern ascent of the Radstaedter-Tauern Pass are the best remains I have seen. Here, through a defile between the present highway and the river, is a pavement of glistening white marble in which the ruts are from four to five inches deep.

There is still another reminder of the ancient Alpine roads—the coins which have been found along them recalling the Roman custom of propitiating or thanking the local god for a safe transit. The monks of the Great St. Bernard have garnered over 1,600 such coins in the monastery museum, which date from 150 B. C to the barbarian invasions in the fifth century. On the summit of the Julier in a hole at the foot of one of the two so-called Julier columns—Roman or Celtic in origin—a mass of copper coins has been found whose dates span the four centuries from Augustus to Constantius II. The most curious cache of all, however, was on top of the St. Theodule, a pass over two miles high leading from the Italian Val Tournanche to Zermatt, which I crossed in 1929 A maid from the Old Hospice in 1895 found in the ice a hoard of 54 coins dating from the time of Nerva to that of Theodosius the Great, a period of 300 years As there never has been a road over this pass ancient or modern, such a find is hard to explain. Perhaps a few intrepid merchants dared the glaciers as smugglers do to-day, and left the coins in gratitude.

But we must not confuse these Alpine roads with the great turnpikes running straight to their goals over hills and valleys which we are accustomed to associate with the Romans—the greatest of road-builders. Of such turnpikes we need mention only one, the oldest and at the same time the model of all later ones, the famous *Via Appia* built in 312 B. C. by the blind censor Appius Claudius from Rome to Capua and later extended to Brindisi on the Adriatic. For that road has no peer for longevity. Four hundred years later the poet Statius still called it "Queen of Roads," and after another four hundred years, long after the barbarian invasions, Procopius, the court historian of Justinian's reign, says it was still in good repair, the surface blocks "having neither separated at all at the joints, nor has any one of the stones been worn or reduced in thickness, nay they have not even lost any of their polish." We have only to add that now, nearly fourteen centuries later, parts of this ancient road, especially in the vicinity of the catacombs of Rome and for a few miles further south, are still in use!

Will any of our concrete roads, racked by frost and heavy automobile trucks, last a fraction of the time?

The Alpine sections were far simpler than this and, after all, merely connecting links between the great highways far below. Nevertheless, they formed integral parts of the network of roads which once radiated all over Western and Southern Europe, and far into Asia and Africa.

The difficulty of crossing such mountain roads was of course then far greater than that which confronts travelers in the Alps to-day. Strabo mentions avalanches, layers of ice and roads along dizzy cliffs. In the fourth century Claudian, the last of the classical Roman poets, mentions "the awful paths where many a man has frozen to death, engulfed beneath vast masses of snow along with carts and oxen, where sometimes the entire mountain top plunges down in an avalanche of snow." His contemporary, the historian Ammianus, has left us a vivid account of his own descent of the Italian side of the Mt. Genèvre route above Susa. He speaks of steepness, overhanging rocks, and how in spring men, beasts and carts may all be engulfed in crevasses, the only remedy being to tie the wagons together and have men and oxen hold them back from behind. To avoid slippery ice he says wooden stakes were driven into the safest parts as guide-posts!

No wonder, then, that the Romans felt an aversion to the Alps. Their interest remained always practical, for the mountains were merely obstacles to be overcome in their expansion. Only merchants, officials and soldiers crossed them and never for pleasure, for the Romans never developed any sentimental interest in their scenery, inhabitants, languages, customs, flora or fauna. The story is often told how the greatest of the Romans, Julius Caesar, once while crossing the Mt. Genèvre to his army in Gaul composed an essay on "Analogy" in his curtained litter quite oblivious of the scenery! Such a story is merely typical of the Roman character.

Nevertheless the Romans overcame their dislike enough to build roads over most of the major passes yet in use to-day. Thus of the seven over the western Alps they knew all except the Mt. Cenis and Simplon; of the nine over the central Alps all except the St. Gotthard, Lukmanier and Stelvio; of the six over the eastern Alps they seem to have known all. This gives us a total of seventeen major passes out of twenty-three now in use. And they knew about as many minor ones as well. This seems a small number if compared with the great array of passes, both major and minor, now in use, of which the *Britannica* lists 518 throughout the Great Divide.

Throughout the Middle Ages—that indeterminate period of over a thousand years from the passing of Rome to the bloom of the Renaissance, or, perhaps, to the crisis of the Reformation—the old Roman roads over the Alpine passes were still used. In fact, we have records of very few new routes from that period, and all these were in the Western Alps.

Thus we first hear of the Mt. Cenis in a document of 731, and we know that its hospice, one of the oldest medieval ones in the Alps, was founded by Louis le Débonnaire or his son early in the next century. The St. Gotthard, one of the grandest of all, leading from Bellinzona in Italy to the Lake of Lucerne, was known to the Romans as far as Andermatt beyond the summit, but their way further north was barred by the Schoellenen Gorge through whose perpendicular walls of granite the brawling Reuss descends. Not until the chasm could be spanned by a bridge was it possible to reach the northern exit of the pass, and the first "Teufelsbruecke" was not built till around the year 1200, a hundred feet above the abyss. Lastly, the Lukmanier, after the Maloja the lowest and easiest pass from Switzerland to Italy, is known from the records of its famous abbey at Disentis from 776, and the first recorded transit was that of the Holy Roman emperor Otto I, the Great, in the winter of 964–5. It is indeed a matter of wonder that throughout the medieval period so few new routes were opened and so few of the Roman roads were kept in repair. All sorts of reasons for this have been adduced—such as the division of authority among local powers, each responsible for its own section only, and lack of capital. But probably the main reason is to be found in the lack of labor to replace the Roman slaves. A recent historian has said that not one Holy Roman emperor imitated his pagan predecessors, the Caesars, either by building a new road or improving any of the old ones which they had inherited!

What had happened? We know that in the gradual dissolution of the Roman Empire after the death of Constantine the Great in 337 trade everywhere waned, for with the spread of Christianity religion usurped commerce as the chief interest of the Middle Ages. This change was of course reflected in the Alps as everywhere else. Now the merchants of an earlier day were replaced by pilgrims and ecclesiastics on the way to and from Rome, "the threshold of the Apostles."

The first of these medieval pilgrims to wander over the Alps were Saxons of England near the close of the seventh century. The first "English" itinerary describes the return journey from Rome of Sigeric, Archbishop of Canterbury, over the Great St. Bernard in 990—the most important itinerary since the Bordeaux-Jerusalem one composed six and one half centuries earlier. Icelandic pilgrims followed the Saxons around the year 1000. Thus we have an account of a journey from Schleswig to Rome and Palestine and return over the Great St. Bernard by Nicholas of Seemundarson, abbot of Thingeyrar in Iceland, written after his return from a three-years' pilgrimage made in 1151–1154. But what has been described more justly as the first Alpine "Guidebook" of the Middle Ages is the *Annales* of Albert of Stade, which describes his pilgrimage in 1236 from Germany over the Mt. Cenis to Rome to visit Pope Gregory IX. For the return journey the routes over the Brenner and St. Gotthard are described, with alternate ones over the Great St. Bernard and Septimer—five passes in all.

The most popular passes in the Middle Ages were the Great St. Bernard in the west and the Brenner in the east. Between 774–801 Charlemagne crossed the Great St. Bernard certainly twice, and perhaps six more times. In the eleventh century Pope Leo IX crossed the Alps eight times, and four were over this pass. It remained the chief western pass for all manner of men—merchants, soldiers, ambassadors, church dignitaries, emperors and popes, while the Brenner played a similar rôle in the eastern Alps. Thus out of seventy-two transits by German kings between 960 and 1250, forty-three were over the Brenner.

That the medieval traveler faced much the same difficulties and dangers in crossing the Alps as his pagan predecessor is shown by three contemporary descriptions of transits of the Mt. Cenis and Great St. Bernard in the eleventh and twelfth centuries. These dangers, apart from weather conditions, were the lack of food and refuges and, above all, the presence of robbers. Christian hospices, however, gradually replaced the Roman *mansiones* everywhere. Many of these have been restored or rebuilt, and so have survived to our time.

Perhaps the oldest Christian hospice was the one which formerly stood on the summit of the Septimer, a pass leading from Bivio on the Julier route in Switzerland to Casaccia in Italy. From its earliest mention in 831 it is known from documents for nearly a millennium. Abandoned in the tenth century, it was rebuilt around the turn of the eleventh, and again in 1542, and the latter one continued down to 1778. To-day even the site is difficult to identify, as I found in the summer of 1929. In fact, no Alpine pass has suffered such a woeful eclipse as the Septimer. From the ninth to the sixteenth century, it was one of the chief passes leading from the Upper Rhone to Lombardy, crossed by many pilgrims, merchants and German emperors with their armies. To-day its lonely trail is overgrown with shrubbery and almost forgotten, as it is now traversed only by a few pedestrians who use it as a short cut over the longer Maloja-Julier route near-by.

Of all medieval Alpine hospices none has greater fame than the two founded by St. Bernard, "the Apostle of the Alps," which after various restorations still stand on the summits of the passes which bear his name. We know all too little of this courageous archdeacon of Aosta. We know he was born at Menthon, where his ancestral castle still stands above the famous spa of Haute-Savoie. Even the room is still shown from whose window tradition has Bernard leap rather than marry the beautiful bride whom his father had selected for him—the event which sent him into the arms of the church. But even the date of his birth is contested. The one thousandth anniversary of the traditional date was celebrated by an encyclical of the present Pope Pius XI in 1923, in which he is named "protector of Alpine climbers," to which hob-nailed fraternity His Holiness belonged in his youth, when, in 1899, he discovered the "Ratti" route up Monte Rosa from Macugnaga. But now it is usual to push the date forward nearly a century, placing his death in 1081 instead of 1007, and the founding of the hospices between 1045 and 1049.

The Little St. Bernard hospice, for centuries controlled by the brothers of the Great St. Bernard, but now by the religious and military Order of Saints Maurice and Lazarus, has extended hospitality to needy travelers for centuries past. To-day some 15,000 travelers, mostly work-people from Italy, are said to cross the pass each summer and the refuge is kept open during the winter like its sister on the Great St. Bernard, though only the rector and a couple of servants are left with one or two dogs to carry on the work of rescue.

A visit to the loftier Great St. Bernard hospice is far more interesting. An abbey was founded at Bourg-St.-Pierre, eight miles below the summit on the Swiss descent, early in the ninth century. It was destroyed in the following century by marauding Saracens, who had their headquarters on the summit, perhaps in the ruins of the Roman refuge there. Though it was soon rebuilt its importance waned with the building of the hospice above.

The present building dates from the middle of the sixteenth century and its church from 1686. Besides the church it contains quarters for the prior and brothers, sixty beds for wayfarers, refectory, library of some 2,000 books, mostly gifts of travelers, and a museum of natural history, mineralogy and all sorts of Roman antiquities picked up on the pass. In 1898 a large annex, connected by a covered overhead passage, was built directly across the road with seventy beds. In 1925 it was converted into a hotel and restaurant, where all travelers, except those *sans resources*, must stay. Latterly those who arrive by autobus must pass on, in conformity with the ancient idea of a refuge for foot travelers.

I have most pleasant memories of a night which I spent here in August, 1912. I had walked up the Swiss side and was drenched by a storm of sleet encountered near the summit. Many other guests had already arrived by bus, and after a plain supper we all assembled in the cozy library on the second floor, which was apparently the only other heated room in the monastery. For our night's entertainment we were expected to leave a gratuity in a box in the church simply marked *offrandes pour l'hospice.* It is a sad commentary on the ways of tourists that while perhaps 30,000 travelers crossed the pass each season, only a fraction of the upkeep of the hospice was defrayed by such donations. That is why the brothers turned the annex into a hotel, where ordinary tariffs are paid. On a second visit, fifteen years later, I was, therefore, courteously refused lodging at the monastery after the brother who had answered the bell found I was not without resources.

In the romantic novelty of a sojourn at such a height and in such solitude, one is apt to forget how dreary life must be for the brave little band of a dozen monks through the nearly nine months of the year when the hospice is practically inaccessible. Then the few wayfarers are poor, the cold is intense, the snow at times reaches above the second story windows—as dated lines drawn on the walls indicate—and blizzards buffet the summit. The brothers begin their work of rescue at eighteen or nineteen, but rarely finish their vow to remain fifteen years. Broken in health they descend to the dependency at Martigny, and there pass the remainder of their lives.

For, after the Fourth Cantoniera of Santa Maria on the Stelvio route, which is forty-six feet higher, the Great St. Bernard hospice, 8,114 feet high, is the loftiest all-year-round habitation in Europe. The higher Hotel Ferdinandshoehe on the summit of the Stelvio, 9,045 feet high, the Payerhuette, a climber's refuge high up on the side of the Ortler, 9,908 feet high, and the inn recently erected on the Jungfraujoch, 11,340 feet, the highest in the world, are only open in summer. In some years one can not reach the monastery till the middle of July because of the deep snow.

The monks in their work of rescuing travelers in distress are aided by their famous dogs, whose keen scent and endurance make them valuable in tracking those lost in the snow, and in bringing them first aid in the form of brandy. As the breed died out some years ago, Newfoundland dogs are used now. If a body is retrieved it is brought to the tiny morgue at the monastery, and there wrapped in a linen shroud and laid on a table. Here it remains until a second one replaces it, when it is stood upright against the wall with others, a custom common to many monastic orders. Because of the cold dissolution is very slow, and thus the dead man's friends can recognize the body long afterwards. Finally the bones are laid away, in what for lack of a better word, may be called a cemetery. But any real burial here is impossible amid the rocks which cover the summit.

In modern times the Alps have played an ever increasing rôle in war and commerce and, more recently, also in sightseeing. The latter is true of the last century during which splendid highways have been built across all the main passes, and since 1900 automobiling over them for pleasure has become very common.

There have been many historic transits of the Alps by armies in the last four centuries, and here above the clouds many heroic struggles for the possession of the pass-routes have taken place, culminating in those of the World War, when Italians and Austrians thus fought in the Eastern Alps. From a great number of military transits I shall mention only three of the more spectacular, one in the early sixteenth century and the other two three centuries later around the turn of the nineteenth.

The first important military transit in the modern era was that of the youthful Francis I, who with an army of 20,000 men and 75 cannon crossed three passes of the western Alps from Grenoble to

Italy in three days of August, 1515—the Col de Vars, Pas de la Reysolle and Col de l'Argentière. This was prior to the "moonlight" battle of Marignano in the following September, where the French arquebus was victorious over the pikes of the Swiss. Francis's experiences recall those of Hannibal, for he also had to follow bypaths never before crossed by an army and to blast the rocks. He had to swing his guns from rock to rock, and finally his cavalry vanguard swooped down upon the Papal troops so suddenly that the leader of the latter, Colonna, afterwards made prisoner, asked if they had descended from the clouds!

In 1799 and 1800, respectively, occurred two remarkable military transits, those of Suvarov and Napoleon. In September, 1799, the gigantic Russian field-marshall—he was six feet and eleven inches tall—when seventy years of age crossed the St. Gotthard on his return from North Italy where he had been fighting the French revolutionary troops. In the Schoellenen Gorge on the Swiss descent occurred one of the most terrific battles in Alpine history between his men and the French who barred the way, a struggle lasting four days and ending in the retreat of the latter. The battle is commemorated by a granite cross thirty-six feet high and a Russian inscription cut into the rock-wall above the present *Teufelsbruecke,* where the struggle took place.

Napoleon's passage of the Great St. Bernard with 36,000 men in 1800 is, perhaps, the most famous in modern times, though a good deal of its fame seems fictitious. During the Italian campaigns of 1798 and 1799 French and Austrian troops had repeatedly crossed the pass, and in the latter year the Austrians were unable to dislodge a garrison of 180 Frenchmen then quartered in the hospice on the summit. The next spring Napoleon sent his army across *en échelon* during the week of May 15 to 21, and then followed in person, starting from Martigny on the Rhone before dawn of the twentieth.

Painters have pictured his crossing the Alpine snows at the head of his troops fully caparisoned and riding a dashing charger. Nothing could be further from the truth, for he wore his usual grey surtout and was seated upon a mule in the rear of his last regiment! Moreover, he had only three companions, his aide Duroc, his secretary Bourrienne and a local peasant guide, with the latter of whom he whiled away the tedium of the journey in conversation, and to whom he later gave a house and field to facilitate his marriage. He lunched at Bourg-St. Pierre at the mouth of the Valsorey Gorge eight miles below the summit. The tiny inn there has ever since borne the grandiloquent title of *Hotel du Déjeuner de Napoléon Premier.* On one of my walks over the pass I had the honor of sitting in the armchair in which the First Consul sat, and listening to the tradition that Napoleon's meal consisted of eggs, toast and coffee like my own!

On reaching the summit he stopped at the hospice only long enough to thank the monks for their entertaining his troops. In gratitude he promised he would place them in charge of the hospice on the neighboring Simplon over which he had already planned a military highway, and to this day both hospices are under the Augustinian Order. He glissaded on the Italian descent like any tourist of to-day, and spent the night at the hamlet of Étroubles, having covered forty miles astride his mule that day! On the following day he continued on to Aosta and Bard in preparation for his victory to be won at Marengo on the fourteenth of June.

Such transits as those described followed the old Roman-medieval roads. Before Napoleon little road-building in the modern sense was known in the Alps. To be successful such construction required the use of powder to break the rock, and it is curious how slowly blasting-powder came into use. We first hear of "powder-blasts" toward the end of the Middle Ages in connection with "Kunter's Way," a two-mile section of the Brenner built in the fourteenth century. Again in the fifteenth, between 1481 and 1483, Duke Sigmund of Tyrol built another section of the same pass-route by splitting the rock with "fire, sulphur, and iron." But powder on an extensive scale was first employed in 1697 in the construction of a rock-hewn road through the Berguen Gorge of the Albula. And we hear little more of its use for a century thereafter.

It was Napoleon, then, who, during his temporary hold on Switzerland and North Italy, gave the modern impetus to Alpine road-building, an impetus comparable with that of Augustus eighteen centuries before. For, during his transit of the Great St. Bernard just described, he experienced the difficulties of transporting an army over a lofty pass without a good road. His artillery was then as badly impeded by natural difficulties in ascending the Valsorey Gorge—up which his cannon had to be dragged encased in hollow logs—as Hannibal's elephants had been.

Between 1800 and 1810 Napoleon had four military highways constructed over the western Alps: the coast-road from Nice to Genoa, including the *Grande Corniche* to Mentone, and those over the Mt. Genèvre, Mt. Cenis and Simplon. Curiously he did not build one over the Great St. Bernard, where a modern road was not completed on the Swiss side till 1893, and on the Italian, including the connecting link over the top, till 1905. He also began a road over the Col de l'Argentière, and planned another over the lofty Umbrail far to the east, which was not finished till three years after his death on St. Helena, and was restored between 1899 and 1901. Before the 1830's were over many other pass-roads had been built—notably those over the Simplon, Julier, San Bernardino, St. Gotthard and Stelvio.

In the modern period only a few major pass-routes have been opened, even fewer than in the medieval period preceding. Perhaps the best example of such a new route is that over the Stelvio in the Central Alps. Here the Austrian Government constructed a military road in 1820–1825 as a feeder into the Umbrail route then being built. Its construction was a continuous struggle with snow and ice at a height theretofore open only to expert climbers, a truly astonishing work of engineering skill.

Railways over the passes began with that across the Semmering in Austria, built 1845–1854. The seventy-fifth anniversary of the first official transit by the then youthful Franz Josef was celebrated on April 17, 1929. It was followed by a railway over the Brenner in 1867, and that by the boldest and most spectacular mountain-railway in the world, the one built over the St. Gotthard between 1872 and 1882. For this railway has 324 bridges and 80 tunnels—including the great one under the pass to be mentioned—three of which are spiral in form on the Swiss ascent and four on the Italian.

With mountain-railways began the piercing of the passes by tunnels. The first one beneath the Semmering is only 1,581 yards long—a little less than a mile. To-day five great tunnels cut the Alps, three through the main divide and two wholly within Switzerland and Austria, respectively. The oldest of these is the so-called Mt. Cenis Tunnel, which runs beneath the Col de Fréjus, some seventeen miles southwest of the Mt. Cenis Pass, and connects Modane in France with Bardonnechia in Italy—a distance of eight miles with the approaches. It took fourteen years to build it, 1857–1870, and the engineering was so accurate that the borings, begun simultaneously at either end, joined almost exactly in the center.

The St. Gotthard Tunnel, connecting Goeschenen in the Schoellenen Gorge in Switzerland with Airolo in Italy, is nine and a quarter miles long, and required ten years, 1872–1881, to complete. The longest railway tunnel in the world is still the Simplon, over thirteen miles in length with its approaches. It has parallel tubes, built in 1898–1906 and 1912–1922, respectively, for one-way traffic. The culminating point of the tunnel is 4,270 feet below Napoleon's highway over the pass, and the encircling mountain crest above rises nearly 3,000 feet higher yet!

The longest tunnel wholly within Switzerland is the Loetschberg, nine miles long, beneath the Gastern Valley and Loetschen Pass on the long road from Brigue to Frutigen, opened in 1911 after four and one-half years of work; while the longest in Austria pierces the Arlberg, connecting St. Anton and Langen on the route from Innsbruck in the Tyrol, six and one-third miles long, constructed in 1880–1884.

Nor should we omit the short tunnel up the Jungfrau built 1896–1912. This ascends through the interior of the mountain far above the snow-line at a maximum gradient of one in four to Jungfraujoch, the highest railway station in the world—a unique triumph of Swiss engineering. But one should not make the mistake of thinking that the railway has done away with the famous climb to the top of the mountain. For it still takes nearly four hours in good weather to cross the Jungfrau Glacier far below the inn, and then to climb the steep ice-covered knife-edge beyond to the top. But fatigue and the danger are forgotten in the magnificent panorama over the Bernese Oberland and the Alps of Valais, a view stretching from Mont Blanc to Monte Rosa, and including the Matterhorn and many of the best-known peaks of Switzerland.

The automobile has long since found its way over all the major passes, and soon it will have its own tunnel, one under Mont Blanc, the monarch of European mountains! Back in 1854 a railway tunnel was proposed beneath between Chamonix in France and Courmayeur in Italy to shorten the journey from Genoa to Turin. But in 1934 the plan was changed to a motor tunnel, with double tubes, like our Holland Tunnel under the Hudson, to connect Chamonix with Entrèves near Courmayeur, a distance of eight or nine miles long, and this may soon be a reality. The pressing need of an automobile route of this kind between France and Italy is evident from the fact that out of six existing Alpine roads across the frontier of 230 miles between them only one—the Riviera route—is open in winter.

This brief sketch of the story of Alpine roads has shown that the use of most of the major pass-routes has been continuous from prehistoric times to the present. Long before the advent of man in the Alpine solitudes, nature had marked out just where such routes could go. Their story, then, is merely the gradual use man has made of the passes throughout the ages. Their number and location were fixed for all time by the natural configuration of the Alpine chain.

NEW EVIDENCE (?) FOR "EXTRA-SENSORY PERCEPTION"[1]

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AMONG the many factors making for the progress of science in recent years, one of note has been the general recognition of the importance of science in promoting human welfare. This recognition has been fostered by a number of able writers, gifted with the ability to make abstruse topics plain to the general reader. Creative men of science who can write with such literary grace as a Huxley or a James are rare indeed. So to such middlemen of science as Clendening, Kaempffert, Wiggam, Slossons, de Kruif, etc., both research men, who require public support, and the public, whose well-being is aided by science, may well be grateful.

Naturally, occasional mistakes are to be expected. Discoveries which appear to promise great benefits will sometimes give rise to propaganda for application before possible bad consequences have been fully considered, as, for instance, was the case when the drug scopolamin was first discovered, and the alleviation of suffering in childbirth had to be weighed against the risks of still birth. But on the whole, public interest in and encouragement of scientific research is surely an asset, and, just as surely, this interest can not be had if the results of research are set forth only in the difficult technical phraseology of the professional journals.

Yet, grateful as scientists are to those who make science known to the world, and however inured they may be to the occasional blunders of untrained eagerness, many psychologists have been startled by the contributions of a recent recruit to the ranks of these educators, Professor Ernest Hunter Wright, chairman of the Department of English Literature at Columbia University. Although systematic investigation of the problem is hardly more than begun, he has decided, on the basis of some preliminary studies partially reported by Professor J. B. Rhine, of Duke University, and without taking account of the negative results of other researches published both before and since those of Rhine, that the existence of the capacities termed clairvoyance and telepathy has been established beyond all doubt. Accordingly, he has published two articles[2] giving an exposition of the supposed proofs, and some entertaining theoretical speculations. These utterances, coming from a high ranking instructor in one of our leading universities and therefore supposedly authoritative, have received a good deal of publicity.

Concerning the theories, no comment need be made at present. We would suggest that they be held in reserve until such time as it may be known whether there is anything to explain. For, while Professor Rhine's experiments have yielded some interesting results, it is quite certain that neither he nor any of his followers has so far given proof of the existence of either clairvoyance or telepathy. It is unfortunate, but true, that it is easy to utter sweeping generalities, on the basis of a few striking cases, which will appeal to the general public and secure adherents, and which, once implanted in the public mind, will "flourish like a tree planted by the rivers of water," and can only be eradicated with extreme difficulty. For disproof, like genuine proof, has to be founded on thought rather than on emotion.

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[1] A critique of Professor J. B. Rhine's studies, in reply to the articles by Professor E. H. Wright, published in *Harper's* for November and December, 1936.

[2] "The Case for Telepathy," *Harper's*, November, 1936; "The Nature of Telepathy," *Harper's*, December, 1936.

Since Dr. Rhine's reports have led to investigations in many other institutions, it might seem unnecessary to prick the bubble, as the truth eventually will out and the craze subside. But meanwhile the public is being misled, the energies of young men and women in their most vital years of professional training are being diverted into a side-issue, and funds expended that might instead support research into problems of real importance for human welfare. This has gone so far that a new *Journal of Parapsychology* has been founded. On all counts, the request of the editors, in their preface to the first issue, that their studies be given searching criticism should not go unheeded.

My first direct acquaintance with the more scientific approach to "parapsychological" problems came when, as a member of Hugo Muensterberg's graduate seminar at Harvard in the season 1913–1914, I heard his comments on his visits to the home of little Beulah Miller, in Warren, Rhode Island. The clue to her apparently astounding telepathic ability turned out to be her response to involuntary movements on the part of others in the family, movements made when they were following her counting, or running through the letters of the alphabet to spell out the desired word.[3]

A few years later appeared the report by John Edgar Coover on his investigations of psychic research at Stanford, a notable example of painstaking, thorough research, and exact treatment of numerical data. One section of the volume reports on experiments in card guessing, and so is of special interest for comparison with recent work. No justification for belief in any sort of occult powers was found.[4]

One more study ante-Rhinum is perhaps worth recalling—the test conducted by Sir Oliver Lodge, with the aid of the British Broadcasting Commission. Sufficient comment is supplied by the heading of one of the newspaper clippings in my files—"20,000 REPLIES, MOSTLY, WRONG, IN PSYCHIC TEST Letters Reveal Amusing Variety of Bad Guesses —A Few Pretty Near Right," etc. That performance more or less dampened the ardor of the public for this particular brand of mystification until it was revived by Rhine, whose studies appear to the uninitiated to have reinstated scientific method in this field. That this was his intention may be taken for granted.

For the purpose of a definite target, and without going into minute detail, extracts from the general remarks on the first page of Professor Wright's second article will serve:

> the evidence is the outcome of more than a hundred thousand tests, simple but purely scientific, made by Professor Rhine and his associates in Duke University. . . . The . . . various tests in question were all made with a pack of cards, twenty-five in number. Each card bore on its face one of five different designs—a circle, a rectangle, a star, a cross, or a set of wavy lines—and each of these designs appeared on five of the cards in the pack. Anyone who took the test . . . was simply asked to name as many of the cards as he could without looking at them and without other sensory access to them. In pure chance of course he would average one card right in every five, or five in every twenty-five; and as he continued, twenty in every hundred, two hundred in every thousand, and so on. The idea was simply to see whether anyone, or any group of persons, could steadily name enough of the cards right to show that something more than mere chance was at work. About half of the tests were for clairvoyance and the other half were for telepathy.

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[3] *Cf.* Muensterberg, "Psychology and Social Sanity," New York, 1914.

[4] Coover, "Experiments in Psychical Research at Leland Stanford Junior University," Stanford University, 1917.

> The result of the experiment was seen to be amazing. About a score of men and women were discovered who could regularly name so many of the cards correctly that there was not one chance in many a million million of their having done their feats by luck or accident; [etc., etc.].

First, we must correct errors in these basic statements. One of the distinctive features of Rhine's studies of telepathy has been the ruling out of the possibility of clairvoyance by having the experimenter merely think of the designs, without using either the cards or any other objective representation of them. As the relative frequencies are not subject to exact control by this method, the chances are variable; and since no records in detail have been given out, it is impossible at present to say exactly what they may have been. The average chances set forth apply then, strictly, only to the tests of clairvoyance. Furthermore, they apply only in the long run; deviations from the theoretical average can not be considered as of much importance in the case of a small number of scores. This point will perhaps carry greater weight in the phraseology of an impartial writer. I turn to page 413 of "A College Algebra," by Henry Burchard Fine, Boston, 1905:

> The fraction a/m, which we have called the probability of an event, means nothing so far as the actual outcome of a single trial, or a small number of trials, of the event is concerned. But it does indicate the frequency with which the event would occur in the long run, that is, in the course of an indefinitely long series of trials.
>
> Thus, if one try the experiment of throwing a die a very great number of times, say a thousand times, he will find that as the number of throws increases, the ratio of the number of times that ace turns up to the total number of throws approaches the value $\frac{1}{6}$ more and more closely.

Fine is speaking of trials in which the probability remains constant, and every trial is independent of every other one. Now, as will be shown below, this is not true of the trials making up a run through the pack in Rhine's work, so only the runs can be considered as giving scores to be compared with chance. Accordingly, the reference to so and so many thousand trials means a great exaggeration of the amount of evidence obtained; a hundred thousand trials yield only four thousand scores, all told, and these must be separated into groups according to the special methods used. But even the four thousand have not been reported. Less than three hundred and fifty runs are listed in the article in which Professor Rhine sets forth his results as a foundation for later research.[5]

Again, while it is true that some of the experiments were carried out at a distance, in a large part of the clairvoyance tests, the cards were both handled and seen (face down) by the persons tested, and, as will appear, this sensory access contributed remarkably towards the more successful series of runs.

Finally, as to the score or so of men and women with such remarkable ability *regularly* to name the cards, etc. Here it seems that enthusiasm has outrun the facts. At any rate, no consistently high series of scores, obtained under conditions for which the chances can be calculated, has yet been published.

II

The whole argument rests on a supposed difference between actual results of the tests and those to be expected by chance, so it is clearly essential to make sure of estimating the chances correctly. Professor Wright speaks of the average scores by chance. Not all chance scores are the same, however, as any one who ever took part in a game of chance knows full well. Pure chance will give some high and some low scores. How are the proportions of these to be estimated?

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[5] *Journal of Abnormal and Social Psychology*, 31: 216–228, 1936.

For this purpose Coover used the binomial theorem, of which many of our readers doubtless retain some vague and perhaps not wholly affectionate memories, as its very great importance is rarely explained to high-school students. The terms of the binomial expansion, as will be shown, give the appropriate chances for the method of experiment followed by Coover. Rhine, however, modified the plan of experimentation in such a way as to increase the chances of extreme scores, both high and low, but used for calculation of chances, as an approximation to the binomial expansion, the normal probability curve, which underestimates the relative frequency of high scores by chance. So his estimates are doubly at fault.

In his experiments on card guessing, Coover used ordinary playing cards, omitting the face cards The pack of forty cards was shuffled and cut before each single trial of a series, and guesses were scored as to correctness of color, suit and number, the chances of success being $\frac{1}{2}$, $\frac{1}{4}$ and $\frac{1}{10}$, respectively, and the expected distributions of scores given by the terms in the expansions of $(\frac{1}{2}+\frac{1}{2})^{40}$, $(\frac{1}{4}+\frac{3}{4})^{40}$, and $(\frac{1}{10}+\frac{9}{10})^{40}$. To show that this is correct, consider a very simple case, the guessing of color, with only three trials in a set. The drawings of the cards can be of four sorts—three black, two black and one red, one black and two red, three black. The chances of these four sorts are given by the terms of $(b+r)^3$, *i.e.*, $b^3+3b^2r+3\ br^2+r^3$. There are three different ways of getting two black and one red, or one black and two red, but only one way of getting either three black or three red. If there is no such thing as clairvoyance, so that the guesses are random, like the drawings of the cards, then the chances of the various possible guesses can be described in the same way, provided the person guessing has no bias in favor of one of the colors. Then the chances of the possible scores —0, 1, 2 and 3—can be obtained by finding the relative frequency of these scores given by scoring each of the eight different arrangements of three cards drawn—bbb, bbr, rbb, brr, etc.—against each of the eight different arrangements of three guesses. The frequencies from the sixty-four matchings are found to be 8, 24, 24, 8, as given, letting *p* stand for success and *q* for failure, by the terms of $64\ (q+p)^3$, p and q each having the numerical value $\frac{1}{2}$. The chances, instead of the frequencies, are given by the terms of $(q+p)^3$. Q. E. D.

Rhine desired to test for pure clairvoyance, ruling out telepathic influences arising from the experimenter's knowledge of the run of the cards and of the scores in the course of a set of trials. So he changed to shuffling the pack at the beginning of a set, running through the twenty-five trials possible with his special pack, and then scoring the record of the guesses against the arrangement of the pack. He did not realize that this method altered the chances. To prove that it does, consider another simple example—tests with small packs of six cards containing three groups of two similar items each. The binomial appropriate to this case for Coover's method of shuffling before each drawing is $(q+p)^6$, with *p* of numerical value $\frac{1}{3}$ and *q* $\frac{2}{3}$. Possible scores run from 0 to 6, and multiplying by 729, so as to give whole numbers—which amounts to setting down the theoretical frequencies for a series of 729 sets of six trials each, we have:

Scores	0	1	2	3	4	5	6
Frequencies	64	192	240	160	60	12	1

Rhine's method involves no drawings, as the pack is fixed, but only various arrangements of the given cards. For this special pack, there are 90 different arrangements, all equally likely to occur. As the person guessing is supposed to be aware of the method used, his guesses can be expected to follow a similar plan, so the appropriate frequencies will be given by scoring any one of the possible arrangements against itself and all the rest. The result is:

Scores	0	1	2	3	4	5	6
Frequencies	10	24	27	16	12	0*	1

* No scores of 5, because if five match, all six must.

The reader can easily check up on this list by comparing with the arrangement *a a b b c c* various other positions of the letters, such as *a b c c a b,* which scores 1, *c a c b a b,* score 2, etc. To facilitate comparison with the binomial frequencies above, multiply those just given by 8.1, and take the nearest whole numbers, giving:

Scores	0	1	2	3	4	5	6
Frequencies	81	194	219	130	97	0	8

Both distributions average 2 hits, but what a difference in the proportion of extreme scores!

The binomial, then, underestimates the frequency of high scores. But Rhine does not use the binomial; he substitutes the normal probability curve—a symmetrical curve which is the limit approached by the binomial $(\frac{1}{2}+\frac{1}{2})^n$, as n increases without limit. It is also approached, though not so rapidly, by the binomial when the two fractions are unequal, provided neither is extremely small, but in this case, the approach is only for scores not very far from the average. Rhine, however, does not restrict his use of this approximation to very large numbers of trials; he uses it whatever number he happens to be evaluating, and he pays attention chiefly to high scores, for which the normal curve estimate is never accurate. For our simple sample pack the normal frequencies would be

Scores . .	−2	−1	0	1	2	3	4	5	6
Frequencies	1	8	56	173	252	173	56	8	1

(one score of the 729 is left unaccounted for)

The absurdity of using a function which implies the existence of negative scores needs no argument. Rhine pays no attention either to the normal distribution as a whole or to his own score distributions, but merely adds up the hits of the runs in a series, and then evaluates the total, with reference to a normal curve supposedly approximating the binomial having the total number of trials as exponent. This is a very crude process and is clearly unjustifiable for evaluation of high scores, when these differ from the chance average more than the latter does from zero, for the occurrence of any such score reveals that the distribution can not be normal. The illustration also shows that, as remarked above, the normal curve estimates of high scores fall short of those given by the binomial, which in turn fall short in comparison with the valid distribution. For this special case the totals of the scores higher than 3 are 65, 73 and 105, respectively.

The same sort of difference holds good in general, though of course the exact figures depend upon the make-up of the pack in question. For Rhine's pack of five sets of five, there are over 623 trillions of different arrangements, so that a solution by tabulation and comparison is beyond human capacity. A solution by higher mathematical methods has been completed this season at McGill, and will be published in a more technical article.

The simple illustrative problem can be used also for the promised demonstration of the linkage between the single trials of a run through the pack, when the pack is shuffled only at the beginning of the run. For the six-card pack, the chance of success in guessing on the first trial is $3 \times \frac{1}{3} \times \frac{1}{3}$, or $\frac{1}{3}$. (The chance of the first card being an *a* is $\frac{1}{3}$, the chance of the first guess being an *a* similarly $\frac{1}{3}$, so the chance of a score on *a* is $\frac{1}{3} \times \frac{1}{3}$. As *b* and *c* count similarly, the total chance of a score is three times as great.) The chance of success on the second trial, after success on the first, is $(\frac{1}{5})^2 + 2(\frac{2}{5})^2$, or 9/25, *i.e.*, 0.36, instead of 0.333. . . . The chance of success on the second trial, after failure on the first, is only $(\frac{1}{5} \times \frac{2}{5}) + (\frac{2}{5} \times \frac{1}{5}) + (\frac{2}{5})^2$, or 8/25, *i.e.*, 0.32. So the trials of a run are not independent and the chances are not constant, as is required for the use of the binomial theorem. The same kind of calculations can of course be made for Rhine's E S P packs, and with the same sort of relations between the results.

To conclude this section of the argument, the chances for a few scores, as estimated by the three methods, will be set down for comparison. (1) is actually used by Rhine as an approximation to (2), which he believes to be theoretically correct. (1) is more convenient because tables of the normal curve are available. But (3) is the valid series for his method of conducting the tests.

Score	(1) Normal Curve $\frac{1}{\sqrt{8\pi}} e^{-\frac{x^2}{8}}$	(2) Binomial $(\frac{4}{5}+\frac{1}{5})^{25}$	(3) Matchings in Permutations of E S P pack
1	.0270	.0236	.0255
3	.1210	.1358	.1369
5	.1995	.1960	.1937
7	.1210	.1108	.1145
8	.0648	.0623	.0636
9	.0270	.0294	.0312
10	.0088	.0118	.0135
11	.0022	.0040	.0042
12	.00044	.00117	.00152
15	.0000007	.0000115	.0000192

These calculations are for scores from a single run. When several runs are combined to give a total score, the discrepancy increases the larger the number of runs in question, and especially for high scores. Unfortunately, while (1) is easily adjusted for application with any number of trials, (2) and (3) have to be recalculated completely for each number of runs combined. This requires considerable labor for (2), a prohibitive amount for (3), so there is no method available for evaluating merely the total score of a small number of runs. A crude estimate of the significance of a series of scores can be made when their fluctuation—not merely their total—is known. The only completely satisfactory test requires a large number of actual scores, whose distribution can be compared with the chance series. The decimals listed in (3)—the complete series, that is to say—have simply to be multiplied by the total number of scores in question, to give the chance frequencies needed.

III

If Dr. Rhine had published complete reports of the scores from his experiments, his error in estimating the chances would not be so misleading. But he has selected for comment only the more fortunate results, a policy which is quite indefensible in any case, and worse still when the significance of the items reported is so much exaggerated.

The unusual always attracts attention, and is easily made a source of mystery. Once, many years ago, my hand at bridge consisted of all the spades in the pack, an event to be expected only once in 779,737,580,160 times. But as the same is true of every other hand that can be mentioned, there was really no occasion for great wonder, although, of course, not all hands are equally noticeable and desirable.

Perhaps, in very truth, no event ever recurs in its entirety. Even to our limited insight, it is evident that the more completely any complex event is described, the less likely is what we have observed to be experienced again. But though every occurrence may be thus unique, many of them are in terms of human interests and needs substantially equivalent, while others stand out as especially desirable or undesirable. Thus, in card guessing, a perfect score is no more of a rarity than any specified one of the many possible ways of getting an average score. In Rhine's clairvoyance tests, whatever one's score may be, the chance of getting that particular score in exactly that way was only one out of 623 trillions. But we pay attention only to the scores, conveniently forgetting the low ones, accepting the ordinary run at or near the average as due to chance, and marvelling at the high ones.

So, when Dr. Rhine says that one of his students has made a total score that could be expected to occur by chance only once in a hundred quintillion times, the natural tendency is to believe the score could not have been obtained by chance at all, that it must be explained by some hidden power, etc., etc., without inquiring what this same student may have scored on other occasions, and to what extent the peculiarities of the experimental procedure may have contributed. Even the skeptical scientist, reading such a statement, may be somewhat intrigued before he pauses to reflect and look over the data. The evidence which Rhine evaluates as a series of 1,625 trials is really a set of only 65 runs, with scores ranging from 1 to 12, average 7.4, which does not seem to reveal any very consistent or marked capacity. The series was conducted by the "down through" method, *i.e.*, the cards were shuffled and cut and then not handled further until the check-up, so that the pack was in sight during the guessing, but not the separate cards, the subject endeavoring to name the cards from the top down. The shuffling was frequently done by the subject himself, the cut always by Dr. Rhine. Rhine says that the best scoring was done with the last five cards, at the bottom, and next best with the five at the top. (No figures stated.) Was there perhaps some sensory clue to the identity of cards in these places, definite enough to raise the average two points above the pure chance level, so that, except for that discrepancy, the scores vary as if merely due to chance? Some such conclusion is suggested by tabulation of the scores.

Keeping this possibility in mind, it is interesting to turn to another selection reported from the work of the same subject, in which, after the pack was shuffled, he held it face down, tried to name the top card, removed it and tried the next, etc., the scoring being done at the close, as with the "down through" series. In this work, the scores average 9.5 instead of 7.4. Is this better clairvoyance or a better opportunity for slight sensory clues to improve the guesses? The separate run scores fluctuate as widely as those of the other series, but at a higher level—from 4 to 15.

Another series, also from the work of this subject, is most helpful towards supplying the answer. For this series, testing "clairvoyance at a distance"—the experimenter and subject working at various distances in different college buildings—rules out any sensory clues. The average score is 7.5, a trifle above that of the "down through" series, but the scores range all the way from 0 to 13 and are in general more scattered than those of the other series, and so much more suggestive of pure guesswork. In Rhine's report, the series is subdivided into four groups. A formal calculation of their significance—taking into account the amount of fluctuation in the scores, which Rhine ignores—shows that Group A remains significant, Group B is just above the borderline, and Groups C and D are well within the limits of ordinary chance accepted by scientists as not demanding special investigation and explanation. Taking all the groups together, the results are positive and somewhat significant, perhaps sufficiently so to warrant further study of the problem. This is the strongest claim that can be justified by this evidence, especially in view of the many hundreds of scores not reported. The usual methods of calculating significance are intended only for evaluation of random samples, and it must always be borne in mind, in reading Rhine, that the scores listed were not selected impartially, as random samples, representative of a mass of evidence too great to be reported as a whole. They are special series picked out as seeming to make a case for the favored theory.

Perhaps the objections to use of selected evidence can be made clearer by a comparison of the present problem with the more familiar one of the interpretation of scores in intelligence tests or other examinations. Although we may still be unable to agree upon an exact definition of intelligence or scholarship, there is no doubt that these desirable attributes exist. A small degree of apparent success in such a test as the Army Alpha, first used in examining recruits in 1917 and 1918, can be got by pure luck. An illiterate, marking the pages at random, may perhaps appear to earn four or five points, but any considerable score depends upon real ability. The average college student scores in the neighborhood of a hundred and fifty points, and all scores of which any use is made are so far from chance that a single test is a reliable measure. Teachers' marks in school and college are, it must be confessed, far from precise measures, but even so, high marks do usually imply high scholarship. In Rhine's experiments, the very existence of the capacity tested for is in question, and all the single scores that actually do occur can occur by chance. Isolated scores, then, have little importance. Conclusions can be validly based only upon the relative frequencies of the high and low scores obtained, and so *all* that are obtained must be taken into account.

The essence of this method of study lies in the opportunity for comparison of actual with mere chance results, by restricting the calls to items for which chances can be calculated. No valid comparison is possible unless either all evidence, or if that is too unwieldy, a sample taken entirely without bias, is compared with theory. In such an experiment, as in any game of chance, when only a comparatively small number of scores is secured from each subject, some will score high, some low, the great majority at or near average, merely by chance. If the entire distribution of scores is large enough to make an adequate sample, and is found to conform, within reasonable limits (not to go into technical methods of evaluation), to the chance series, then there is no positive evidence, and therefore no more excuse to select a high score than a low one as having any special meaning. Both, in proper proportions, are to be expected by chance. Lifting out of their context the scores of the more fortunate subjects, and then evaluating them, without regard to the existence of all the rest, as if they were a random sample, and thus deducing the existence of some special capacity, begs the whole question at issue. Any genuine factor apart from chance would show up in a departure of the total distribution from the chance series. This given, examination of the data might reveal whether such factor is more or less general in its influence or confined mainly to a few subjects.

If any one were found to secure *consistently* high scores, a further study of his abilities could be advocated regardless of the results of others. But no such person has ever been found.

Rhine has given no distributions of his

scores as a whole or any large groups of them. He seems to have been so firmly convinced of the existence of "extra-sensory perception" before he began research that he has never realized such a general comparison might be desirable. Instead, he has simply selected some of the subjects who were most fortunate in the early part of his work and given them further tests. If these had been handled impartially, all would be well. But the fact that these subjects were picked out as promising dominates all their later tests. When good scoring, on the average, continues, well and good. When it does not, when their later results do not pan out, they are said to have lost their former ability, although no proof, on the basis of an adequate random sample of their scores, has been offered to show that they ever had any ability. The reader is given no opportunity to judge of this fairly, because complete results are not reported, even for the selected subjects. When for a time they do well, Rhine sets down the scores, over-evaluates them by his customary technique and draws conclusions favorable to his theory. When they fail, that is regrettable, but it has no influence on his conclusions. The special ability is temporarily exhausted or has vanished; its prior reality is never questioned. The poor series are not listed, and their very existence is only incidentally mentioned. Rhine does not go so far as to assume that the supposed capacities vary from hour to hour; good series are reported in full, zero scores and all. He is entirely sincere, and does nothing that from his standpoint would appear to be falsification of evidence. He simply does not realize that such selection of the better series does not conform to the requirements of his chosen method of research, but assumes the truth of the conclusion he is trying to prove.

E.g., a short series—only eight runs, average 10.1—is cited as proof for "telepathy at a distance" (the series mentioned as the "Junaluska Series"), with experimenter and subject, two of the women students, 250 miles apart. Note that this is a telepathy test and can not be evaluated in accordance with the chances calculated for the clairvoyance work. There could, obviously, be no score below zero or above 25. For the rest, the only information made available concerning the possibilities is the series of scores actually obtained. They range from 2 to 19. When due allowance is made for this fluctuation, the series is found not to be significant, even on the assumption that the chance average is only 5. In fact, supposing that the subject's true average is likewise 5, she might, judging from this set of scores, be expected to obtain, by chance, an average as high as or higher than 10.1 in about one case in every forty-two, in the long run. Other results of this subject are even less promising, and are mentioned only to justify Rhine's belief that this series did not involve collusion between the two students, since in other cases, when good scores were particularly desired, she did not get them. But then why assume that she was "telepathic" at all?

All the statistical tests so far mentioned have been *ex post facto*, concerned with the problem, given such and such results, how significant are they? There is a familiar rule, simple and straightforward, for the guidance of the experimenter in the course of a research, in deciding whether a sample set of values is adequately representative. . . . From time to time, calculate the average of all the results so far recorded. Continue the gathering of data until additional values make no appreciable difference in the average. Then the average is valid for the given conditions of experiment. . . . Rhine's procedure with his selected subjects is directly opposed to this rule. He rejects all series of scores that would modify the favorable averages.

Certain other results are reported from telepathy tests in the laboratory. Although the scores are higher on the whole than those in any of the other series, the possibilities of error in the records, and the uncertainty of the chances involved, except that it is quite clear that they were much higher than those in the clairvoyance tests, preclude giving these results any great weight. Apparently, only a partial record was kept, that of the calls made by the subject, in some of the runs two rooms away from the experimenter, with the doors open, but with an electric fan going so as to prevent any involuntary whispering of the experimenter from being heard by the subject. The experimenter had to try to think of the various designs as nearly as possible five times each in a run, but with no written plan to follow, give buzzer signals to call the attention of the subject for each trial, record the responses as heard, or supposed to be heard, check them if correct. Judge the effect on the scores of the almost inevitable tendency, especially in a laboratory so full of faith in E S P, to give the subject the benefit of the doubt in any trial involving some difficulty in hearing or in memory, and the great likelihood of illusions in hearing, the hearing of one call as a different one, especially when the observer gets excited in the course of a good run, and so hears what is desired instead of what is really uttered, yet with not the slightest realization of the possibility of a mistake. The much greater ease in following a lecture or play in one's own language has often been explained as due not so much to differences in understanding what is actually heard, as to the readiness to fill in gaps in auditory stimulation and, as far as conscious experience goes, hear the whole. In such a case, expectation is guided by the context, in line with the familiar usages of the native tongue. In the telepathy tests, success may breed success, in the record, by creating such an attitude of optimism that the observer-experimenter will strongly tend to hear the name of the symbol he has just been "sending." Again, if experimenter and subject happen to have thought preferences in favor of the same one or two of the designs, scores will be increased regardless of any mutual influence. Any experimenter in such work will also tend to form more or less definite order-habits. This possibility was recognized, and precautions taken to counteract it. Cross-checks, applied to *other* series, show these precautions were on the whole successful. At any rate, habits did not become so established that similar plans were used in *immediate* succession. But many of the different arrangements of the designs, that would occur in the shuffling of a pack, would almost certainly not be included among the plans chosen consciously. Some might seem too systematic, *e.g.*, aaaaa bbbbb, etc.; aaaaa bcd bcd, etc., . . . eeeee. On the other hand, others with no apparent plan would give no ready means of keeping to the equal frequencies desired. If such helter-skelter arrangements are avoided, the range of possibilities is reduced; if not, there is more scope for symbol preferences which may be correlated with those of the subject. Rhine, as a means of controlling frequencies, coached his experimenters to plan by groups of five, which leads most naturally to five sets of one each of the five designs, thus very much reducing the number of different arrangements. (From 623 trillions down to less than 25 billions, subject to further reduction by avoidances, etc.) This extreme he seems to have tried to prevent, but the measures taken for the purpose are not such as to result in anything like the total possibilities of shuffling. There has been no mention of any attempt to keep secret the instructions given for the conduct of the tests. It would be strange if students interested in the work did not sometimes discuss various possible arrangements of the symbols. However that may be, subjects would surely tend to follow somewhat the same general sort of procedure as the experimenters—which means a marked increase in the chances of high scores. As the subjects were informed of their success at the ends of the runs, adoption of plans of the type used by the particular experimenter would be favored. Skill could thus be developed just as it is in various familiar card games. Indeed, a good player might adjust to this experimental situation almost immediately.

Without specific records of the exact sequences of the designs chosen by the experimenter and the corresponding calls of the subject, no worthwhile estimates of the chances can be made. No such records have been published. They were kept, apparently, for some parts of the work, but not for the series cited and partially listed in Rhine's article, as important evidence. This evidence accordingly is valueless.

If it is really important to test for *pure* telepathy, which precludes any proper estimation of chances in advance, then surely complete records should be made, so that calculations can be worked out from the results. Of course a written record is open to the same objection as the use of cards—the opportunity for clairvoyance. So dictagraph records should be taken. Then all the arrangements actually occurring in the records of each experimenter and subject should be listed and classified, and the chance score frequencies tabulated for comparison with those actually obtained.

To sum up: Professor Rhine's argument for extra-sensory perception rests upon the differences between scores obtained and those to be expected merely by chance. It has been shown (1) re clairvoyance:

(a) that he greatly underestimates the chances for high scores;

(b) that he pays no attention to the internal inconsistency of the results;

(c) that he draws conclusions from selected portions of the evidence, in a way that assumes the truth of the very theory he wishes to prove;

(d) that among the selected series, those giving the highest scores also offer the greatest opportunity for sensory clues to the identity of the cards.

(2) re telepathy: that the chances in this part of the research are unknown, so the supposed evidence can not be used.

The complete data have not been published, even in summary form, so as to permit of an independent verdict. The whole research is therefore quite inconclusive.

THE NEW DOGMATISM

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MANY of us professional men of science have long since demolished, to our own satisfaction, most of what currently passes as "religion," and have even called in question the very existence of "theology" as a legitimate object of inquiry. For lack of any real evidence to support their claims, these are subjects which must perforce be taught dogmatically and authoritatively. But science, on the contrary . . . ! We have all stressed this invidious comparison, and I think on the whole that we have been justified in doing so. But the difference is not such an absolute one as many have been led to suppose. To the man in the street nearly all science is taught dogmatically. He accepts it from authorities whom he is led to believe that he can trust. Some of this matter, to be sure, appeals to him as inherently reasonable. Much of it, on the other hand, is downright unintelligible to him, or it may even challenge his common-sense.

So much for the "man in the street." What about those of us who spend part of our time indoors—say in laboratories and libraries and classrooms? William Graham Sumner, whose opinion of the intelligence of the "masses" was none too high, remarked sagely that outside of our own specialties we all belong to the masses. Outside of these specialties, we take our science, for the most part, on authority. It is a different kind of authority, to be sure, from that upon which a devout peasant accepts the miracles wrought by his saints' bones. Our direct sources of information are men who have earned their right to be trusted. And more important yet, they can often show us the evidence for their statements, or at least they can tell us how—in theory, at least—we can find this evidence for ourselves. However, as science expands, and the sphere of each specialist contracts, the proportion of our knowledge which we individually get on authority rapidly increases, and the proportion which we get by observation, experiment and constructive thinking rapidly diminishes.

Furthermore, the day has nearly passed when we even go to our authorities for their factual "results." For the most part it is their "conclusions" which we carry away. Outside of the ever-narrowing fields in which we ourselves are authorities, the things which we assimilate from our scientific environment are interpretations often many steps removed from the crude data. Much of the time, we do not even know what these crude data are like. Nor would they mean anything to us could we see them. And so, not only do we depend more and more upon authority for our scientific information, but this information, when it reaches us, arrives in the form of abstractions to a large degree divested of living reality.

A worshipper, repeating the "Apostles' Creed," expresses his belief in the "resurrection of the body." A student, reciting in a chemistry class, tells the professor that the "atomic number" of sodium is 11. I do not wish to make too much of this comparison. All I contend for is the probability that to many students "atomic number" is just as much of a dogma as "resurrection of the body," and just as little capable of being translated into terms of human experience. As to the professor—well, there are professors and professors of course. But any kind of an instructor in chemistry will tell the student in a few words just what the expression atomic number "means." The number of positive charges on the nucleus of the atom—what could be simpler? And so, I doubt not, could any bright Sunday-school teacher given verbal account of the resurrection of the body.

The conception of atomic number finds its ultimate justification, of course, in a vast array of observational evidence. But how many of us—aside from one particular brand of chemist or physicist — actually have first-hand knowledge of this evidence, or are even in a position to follow it understandingly if it were furnished us by visual demonstration?

A further perplexity has been added to this whole situation by the increasing application of mathematics to the so-called "fundamental" sciences. Much of this is not the sort of mathematics which the ordinarily well-educated science student from one of our better colleges carries away with him. It is a realm of mental activity into which relatively few persons in the world are qualified to enter. However, unless we fulfil these drastic requirements, we are altogether unable, it would seem, to follow the reasoning upon which some of the most notable scientific generalizations of the day are based. Worse yet, we are even denied the privilege of understanding in any real sense what these generalizations mean. And *a fortiori,* we are denied every right to criticize them. Be that as it may, we do not seem to be absolved thereby from the duty of accepting these generalizations and of rendering homage to those mighty minds which have been able to develop them.

The name of Einstein has become almost a household word throughout the civilized world, and the picturesque head of this mathematical genius is probably as familiar to the public to-day as that of most other contemporary world figures. It is far from my purpose here to question the greatness of Einstein. I am quite willing to accept the appraisement of his fellow specialists on that score. Yet how many persons have the faintest idea what the name of Einstein stands for in the history of science? How many persons—indeed, how many scientists—are even capable of learning this, try as hard as they may? Any well-informed person now has a fairly accurate idea of what the name of Darwin stands for. Or at least he can be taught. And so, in general, with the major results of modern biology. A few hours of well-directed reading will convey to any really educated person the chief discoveries of the Morgan school regarding the physical basis of heredity.

But this question of relativity! That is a horse of another color. Many courageous attempts have been made in recent years—some, indeed, in the popular press—to expound relativity in non-mathematical language. They usually start out with the already familiar idea of the relativity of motion. For a while, the reader follows eagerly. At last he is going to be enlightened! Then he loses the trail, sometimes suddenly with the introduction of some new and unintelligible train of thought, sometimes gradually, after sinking deeper and deeper into what seems to him a bog of paradoxes and *non-sequiturs.* At least this has been, for the most part, the experience of the present writer in reading with care a considerable number of these attempted elucidations.

Any person of average education and brain-power is doubtless capable of attaining some degree of verbal "understanding" of this subject. And even a newspaper column-writer may be able to convey such a purely verbal "explanation" to readers less informed than himself. But all the reader is likely to receive from such sources is a vague, sketchy notion of the kind of problems which the relativist is trying to tackle, along with some bewildering paradoxes which are offered him as unavoidable consequences of the theory. At best he can get only dim and tantalizing glimpses of its real substance.

All this is not, of course, offered as criticism of the theory of relativity. The chief difficulty obviously lies in the attempt to grapple with certain highly abstruse problems by persons whose mental preparation has not qualified them for the task But an almost equal difficulty, I believe, lies in the methods which have been resorted to by the theory's expositors.

In general, the illustrative "experiments" by which the principles of relativity are justified to the reader are purely imaginary ones, involving such things as the observer's moving through space at the velocity of light or moving at an accelerated motion, corresponding to the acceleration of gravity, or involving his ability to read another man's clock or measuring rod, while one or both of the parties are traveling at these furious speeds. And if some ignoramus of a biologist should express mild surprise at this to him unfamiliar method of solving scientific problems, he would forthwith be silenced by reference to certain equations by which Einstein *et al.* have *proved* all these things! And so it goes. These revolutionary doctrines can only be understood—and by the same token, can only be criticized—by persons equipped with a mathematical technique which very few living persons can master.

This does not seem to relieve us, however, of the obligation to accept these doctrines. And they are being accepted with all the authority of a gospel, often, I doubt not, by persons who have no more real understanding of them than the present writer. Why, then, should I presume to withhold my own acceptance? Who am I to dispute the conclusions of the master minds of the century? My answer is that I am not disputing them; I freely grant their probable truth. But I contend that neither I nor any other person can really believe that which one finds to be by its very nature unintelligible to him.

I recall, in this connection, a passage from a catechism, a copy of which fell into my hands many years ago. To the question (quoted, I am sure, with substantial accuracy), "After the priest hath blessed the bread and wine, and converted them into the flesh and blood of our Savior, what remains of the bread and wine?", the young believer is taught to respond "Only its properties." I can see little difference between "belief" of this sort and the avowal of belief in anything else which is equally meaningless to the person concerned.

A few other aspects of the "new physics" are equally relevant at this point in our discussion. The now well-known antinomy regarding the electron—assertedly both a particle and a wave—is a case in point. True, we can not conceive of a thing's being both a particle and a wave at the same time. But what we can *conceive* apparently has no bearing on the situation. Modern physics seems to have definitely abandoned the notion that we must be provided with mechanical models of what happens in the universe. If equations can be found which express the relations in question—if, in the present case, they show how "the particle- and wave-pictures are merely two aspects of the same reality"—that should be enough to satisfy us.

To those of us who use mathematics merely to express quantitative relations among *things,* such a solution of the difficulty is altogether puzzling. A disembodied equation may be highly interesting and valuable when we are concerned with pure mathematics, but it hardly serves as a substitute for a description when we are concerned with phenomena in the physical world. At least this is true for the non-mathematical mind. To an unsophisticated naturalist I fear that this argument that a thing may have the properties of a wave and a particle at the same time is too strongly reminiscent of some of the old-time theological arguments for the doctrine of the "Trinity"

All this, while granting the high probability that the equations which these scholars have devised are rigidly exact in every particular. The important question before us is whether at long last our conceivable space-time models of natural phenomena are to be wholly replaced by a series of equations expressing relations among unknowables. This is the avowed ideal of some of those who are writing in the name of modern physics. "An ideal shines in front of us," says Eddington, "far ahead perhaps but irresistible, that the whole of our knowledge of the physical world may be unified into a single science which will perhaps be expressed in terms of geometrical or quasi-geometrical conceptions. Why not? All the knowledge is derived from measurements made with various instruments."[1] And Jeans writes: "The essential fact is simply that *all* the pictures which science now draws of nature, and which alone seem capable of according with observational fact are *mathematical* pictures."[2] This despite Jean's avowal in another place that recent science, in contrast with nineteenth-century science, "is no longer in flat contradiction with our intuitions and the experiences of everyday life." When the goal set by these mathematicians is attained, real science will be the property of a small esoteric group, while the rest of us, it would seem, will have to content ourselves with crude and misleading visual symbols of reality.

There are some, I doubt not, who look forward to such a situation with entire complacency. Those of us, however, who follow the "natural history" sciences must find the prospect decidedly disconcerting. And, being human, we can hardly fail to resent the strong tinge of arrogance which seems to be implied in such a forecast. We have long been accustomed to invidious comparisons between the "exact" sciences and those which, not being "exact," are scarcely to be regarded as sciences at all. Even some of our biologists seem disposed to concede that only the precisely quantitative part of their domain deserves the name of science. Science is science, it appears, only in so far as it is capable of mathematical expression. That such a definition would exclude some of the greatest advances in scientific knowledge does not seem to disturb those who continue to repeat it.

Psychologically speaking, it is not difficult to understand how an accomplished mathematician might readily fall into an attitude of arrogance toward those of us who work with other tools. He is master of a technique which few of us can handle —perhaps, we may add, that few of us could ever learn to handle with much proficiency. He is quite aware of our utter dependence upon him for the solutions of many of our problems. And he realizes, too, how one-sided this dependence is. While we must appeal to him at rather frequent intervals for help which he alone can give us, he has no real need of anything which we may be in a position to furnish.

Personally, I stand in considerable awe of these men who can fill their pages with differential equations. They have mental powers of a sort which I could never hope to attain. It is true that I stand in almost equal awe of the man who can play six simultaneous games of chess with a blindfold over his eyes, or even the man who can play a single masterly game with the board before him. He too has mental powers which seem stupendous in comparison with my own. However, I can not tolerate this sense of inferiority very long. I recall that the really great chess-players are not often known for any other mental achievements, and I try to persuade myself that some of our most accomplished mathematicians might prove to be "all thumbs" if they were rash enough to enter the field of experimental biology. There is an even chance, too, that this pollicality might not be entirely on the neuro-motor level!

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[1] "The Nature of the Physical World," p. 186.

[2] "The Mysterious Universe," p. 150.

Whether or not the word "science" will ever come to be restricted to the quantitative aspect of natural phenomena I should not be rash enough to predict. If such a restriction (or shall we say perversion?) of the meaning of this word were ever generally accepted, we should have to find another word for that vastly greater field of knowledge not yet reduced—perhaps never to be reduced—to mathematical terms. Here would belong the work of such men as Harvey and Pasteur and Lyell and Darwin, and—despite his ratios—of Mendel. And here will continue to belong a large majority of the most interesting, important and influential contributions to human knowledge, and the output of many of our most original minds. Some enterprising journal of the future might start a contest for the best name by which to call all this!

However, to return from our digression, if we can not follow the mathematical reasoning of these neo-physicists, we can at least understand in a measure some of the conclusions to which their reasoning has led them. And here at times they come into rather violent conflict with the common-sense of mankind. Common-sense, to be sure, has long been abandoned as a safe guide to truth. But it is relevant to point out this conflict in a discussion of the relations of science to current thinking. The wave-particle paradox has already been referred to. Once more, we have been told that if one traveled with the speed of light, he could make a tour of the universe without aging, though coming back to a world which had grown old during his absence. And again it would seem that our old nineteenth-century notions about infinite time are unfounded. The universe started *de novo* only a few thousands of millions of years ago (not a very impressive figure to an astronomer) and has been expanding at a terrific speed ever since. To Eddington it seems reasonable to believe that the earth, of all among the near-infinitude of heavenly bodies, is probably the only home of living beings; also that the present universe is the unique product of creative energy, having not only a beginning but an end. "I would feel more content," he says, "that the universe should accomplish some great scheme of evolution and, having achieved whatever may be achieved, lapse back into chaotic changelessness, than that its purpose should be banalized by continual repetition."[3] Jeans mentions rather casually that "the number of particles—electrons and protons—in the universe is of the order of 10^{79}."[4] The same writer has expressed his oft-quoted conviction that "the universe appears to have been designed by a pure mathematician." Verily we all make our gods after our own images!

The diameter of an electron is said to be only a fifty-thousandth that of an atom. By its very nature it is forever beyond the range of human vision. Nevertheless, most of the popular expositions of twentieth century physics speak with the same nonchalance of manipulating individual electrons and observing their behavior as a biologist speaks of his experiments and observations upon protozoa or bacteria. We learn, for example, that "Heisenberg succeeded in showing that one may choose *either* to determine the place of a flying electron *or* to ascertain its speed with precision, but that there can be no experiment which will fix location and velocity *at once* with the maximum accuracy.''[5] I venture to assert that no popular expositor of one of the ''inexact'' sciences could talk that way and get away with it!

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[3] "Nature of the Physical World," p. 86.

[4] "The New Background of Science," p. 264.

It happens that these speculations of Heisenberg's and some others have been seized upon with avidity by various persons having metaphysical or theological axes to grind. And this number includes more than one scientist of real prominence. One line of argument seems to run somewhat as follows: *If* we were able to see an electron, it would be impossible, for certain theoretical reasons, to determine both its velocity and its position at the same time. Therefore, the electron, at any given moment, has either a definite velocity or a definite position, but does not possess both of these. Therefore, the principle of ''determinism'' or ''causality'' does not apply to the ultra-microscopic world, but only—in a purely statistical sense—to the macroscopic world. And other reasons are given for believing that events in the ultra-microscopic world ''just happen,'' that, for example, one atom out of a million in a mass of radium elects to disintegrate without prompting from any source excepting its own sweet will.[6] Thus ''spontaneity'' and ''free will'' come back upon the scene, stamped with the guarantee of modern science!

Merely to repeat these various assertions is surely not to refute them. Indeed, I should not be so reckless as to attempt to refute them. But many of us have probably formed rather decided opinions as to their reasonableness. And on the principle of judging a tree by its fruits, we may have come to mistrust the methods followed by those who tell us some of these things. Or at least, we may have lapsed from our former attitude of humble acquiescence.

Nor does it seem to be true that all these master minds of modern physical science agree with one another. Those who have followed, even casually, the publicity which has attended the recent developments in physics and astronomy know that the field is beset by controversies. And among the controversial questions have been some of the most vital ones—whether, for example, the universe is finite or infinite or whether or not it is rapidly expanding. Millikan has argued that the ''cosmic rays'' represent a by-product of the creation of matter in space. Jeans and others have been equally convinced that they originate from the destruction of matter. Some writers argue for an indeterminacy which is absolute; and assure us that causality has been banished from science; others argue that this indeterminacy is merely relative to our knowledge. And our elementary units of light and electricity—are they particles which move as waves, or waves which manifest some of the attributes of particles? Or are they simply disembodied equations which scorn representation by any visual models whatever?

Without presuming to question for a moment the mental profundity of some of these exponents of the ''new physics,'' nor the vast importance of their actual discoveries in this field, one can not help wondering whether the up-to-the-minute publicity so widely given to their more speculative utterances through the lay press or through popular volumes of their own authorship is not considerably impairing the status of science in the public mind. There would seem to be a vast inconsistency between the traditional notion of the man of science, with his uncompromising insistence on evidence and his lofty scorn of guesses and unproved assumptions, and the quasi-mystic who tells us all these strange things about space and time and infinity and who describes with such assurance the detailed intricacies of an infinitesimal world forever beyond the range of human observation. And this bewilderment of the layman is surely not lessened when he learns that these master minds are not always in agreement among themselves. Yet, curiously enough, this speculative and controversial part of recent physics appears to be stressed as much as any other one thing in current portrayals of scientific progress in the popular press. So far as the "general reader" is concerned, it would seem to be vastly better if the newspaper columnist would only gather his material from the teacher of elementary science instead of hovering around the notables who are engaged in extending its frontiers. But that sort of material would not, I presume, rate as "news."

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[5] Reichenbach, ''Atom and Cosmos,'' p. 262.

[6] At least one writer has seriously contended that the mysterious genetic ''mutations'' of the biologist are similarly uncaused. We need scarcely point out the paralyzing effect of such doctrines as these on scientific progress.

It was long ago suggested that the growth of science would reach its limits through the unchecked increase of specialization. We should finally have an immense cluster of endlessly subdividing branches, each physiologically isolated from what remained—if anything—of the original organism. This is perhaps an unduly pessimistic forecast. But it does seem certain that an ever-smaller proportion of what we individually "know" will have the vivid reality of something immediately experienced, and an ever-increasing proportion will consist of abstractions and interpretations received from other persons.

However, all this is no reason to discourage the dissemination of knowledge regarding scientific discovery, so far as this is possible. It has long seemed to some of us that the "new physics" has been very largely unfortunate in its interpreters to the laity. Despite some exceptions, there has been altogether too much of what impresses one as "showing off"—too much parade of individual brilliancy and resort to whimsical analogies and startling paradoxes, and too little earnest attempt to make the reader really understand the matters on hand. What some of us would like to find is first of all a clear description of what the experimenter really does and sees, and *after that* an account of his theoretical interpretations. We are too apt to read about "bombarding the atom," "smashing the nucleus," "weighing the electron" and the like, with commonly but the faintest intimation of how all this is done and why these effects are inferred. As Swann pointedly remarks: "We say that we set up apparatus and measure the number of electrons going through a certain hole. We do no such thing. We make settings of certain electrical instruments, and we make readings of others. From our readings and settings we *calculate* these visions of electrons going through holes, and the like."[7] It is unfortunate that this realistic view-point is not more constantly kept in mind by the popular expositor of recent scientific developments, biological as well as physical. Since the foregoing article was submitted for publication, a highly interesting article by an English professor of astrophysics has appeared in the *Atlantic Monthly*.[8] It gratifies me to learn that there are among the physicists themselves some who "view with alarm" the current trends in popular exposition.

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[7] "The Architecture of the Universe," pp. 175, 176.

[8] "Knowledge without Understanding," by Herbert Dingle, *Atlantic Monthly*, July, 1937.

THE DESTRUCTION OF "VERMIN"

By Dr. ALBERT M. REESE
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AT their annual meetings, in December, 1936, both the American Society of Zoologists and the Ecological Society of America passed resolutions condemning the wholesale destruction of our wild animals in the so-called "vermin" control campaigns being waged in so many of our communities. The author was requested by the latter society to write two articles on the subject, for publication in THE SCIENTIFIC MONTHLY and in *Nature Magazine*.

We hear and read a great deal about "our vanishing wild life," but it is doubtful if the average reader realizes the part played in the vanishing process by the so-called "vermin or predator control" campaigns that are sweeping the country.

The term "vermin" is applied, chiefly by sportsmen and dealers in sportsmen's supplies, to those animals, without regard to their beauty, interest or value, which are *supposed* to be harmful to the few species that the sportsman himself wants to kill.

The term as used perhaps originated on the great hunting estates of Europe, where game wardens, often very "hard-boiled" individuals, were paid to protect their employers' game against human poachers and every other danger except the owner's firearms. Most absurd ideas of "vermin" sometimes obtained, as in the case of the warden who destroyed nightingales because, he said, they disturbed the sleep of the pheasants.

Perhaps no such extreme ideas are held in this country, but when more than 69,000 chipmunks are destroyed in a year in one state under the name of "vermin," we, who enjoy watching or making pets of this attractive little animal, wonder if the word "vermin" was not attached to the wrong mammal.

The live-stock interests are probably chiefly responsible for the war of extermination being waged, mainly by the U. S. Biological Survey, against the larger predators of the western states. In 1936, 1,115 wolves, 64,566 coyotes, 6,980 bobcats and lynxes, 287 mountain lions, 173 bears and 6 ocelots were destroyed. What effect this destruction will have on the numbers of destructive rodents in this area remains to be seen. The fur trade is said to be solidly against the policy of poisoning predators, believing that "the very existence of the domestic fur trade is threatened."

There are several groups of people who are interested in wild animals. The smallest, and, in most localities, non-existent, group is composed of those who need the animals for food. The second and larger group includes those who make their living by collecting furs; this group is also lacking in most communities. A still larger group, found in practically all communities, comprises the sportsmen; in this group are also the manufacturers of the arms and ammunition used by the sportsmen.

By far the largest group of persons interested in wild life are those who enjoy watching and studying the live or scientifically mounted animals in the woods, fields and museums. We who belong to this universally distributed group can see no justice in allowing a smaller and generally well-to-do group to destroy, by the hundreds of thousands annually, many beautiful or interesting animals because they are thought, often incorrectly, as we shall see, to diminish the numbers of a small group of *game* animals that the sportsmen want preserved so that they may be killed for sport.

To gain an idea of the kind and number of animals killed in these "vermin" control contests note the results for 1935 in an "Eastern State" as given in Publication No. 59 of the Emergency Conservation Committee.

Species	Number
Gray fox	1,700
Weasel	2,900
Wildcat	188
Mink	404
House cat	8,410
Crows	19,616
Kingfisher	1,546
Snakes	184,702
Carp	331
Rats and mice	115,016
Hawks	7,270
Owls	3,123
Waterdogs	14,571
Gars	462
Blackbirds	783
Sparrows	3,936
Turtles	21,566
Shite pokes	42
Ground squirrel	69,780
Eagles	4
Groundhog	1,203
Eggs (snake, crow, hawk and owl)	1,308
Terrapins	28,572
Starlings	19,186
Red squirrel	7,606
Total	514,225

Note that snakes, hawks, owls and eagles are destroyed as groups, apparently without regard to species.

Let us consider these four groups in turn. The order of snakes undoubtedly includes some species that are of little, if any, economic value to man, and few people would advocate the protection of the more dangerously poisonous ones; but to include, say, the house snake, the black snake and the bull snake in the "vermin" list because an occasional sportsman sees one of these familiar forms in the act of destroying the nest of some game bird is as unjust as it would be to kill all dogs because a sheep-killer is seen in a farming community. Yet in the above list 184,702 snakes were numbered.

The case of the hawks and owls is still worse, as a majority of the hawks and practically all the owls have been shown, by extensive studies of stomach contents and food pellets, to be highly beneficial as destroyers of rodent pests. In some communities only the hawks known to be more harmful than beneficial are permitted on the "vermin" lists, but this does little good, as few people know the species of hawks, especially at a distance or on the wing. To prove that this was true the following experiment was tried: seven well-mounted specimens of our *common* hawks were placed in a row, each specimen numbered; the eleven sportsmen present, all of them educated men, were asked to name, by numbers, the seven hawks; five of the eleven men failed to correctly name a single bird and only one named as many as five of the seven hawks. This experiment was tried on two other occasions, known to the writer, with similar results. Unless, then, a severe penalty be imposed for killing the wrong birds, it is obvious that the naming of certain hawks in a "vermin" campaign is little more than a gesture.

The establishment in 1934 of the Hawk Mountain Wild Life Sanctuary, on the Kittatinny Ridge, in the east-central part of Pennsylvania, was a grand stroke of conservation, as hawks of all sorts were there being slaughtered each year by the thousands, purely for sport.

The eagle case is somewhat similar to that of the hawks, since the average person can not tell the bald from the golden eagle until the former is mature and develops the white head- and tail-feathers.

The bald eagle, which was made our national emblem by act of Congress on June 20, 1782, is generally regarded as a harmless species; the case of the golden eagle is not so clear, but its rarity, in most regions, makes its possible occasional depredations of little importance.

It is thought an eagle can lift an object of its own weight, from 8 to 11 pounds. As a lamb averages from 7 to 8 pounds at birth an eagle *could* carry it off, for a short time after birth, and might kill it for a much longer period, even if it had grown too large to lift from the ground; but to believe that an eagle could carry an eight-year-old boy, weighing 50 pounds, up twenty feet before dropping him from fright, as has been reported, is asking too much of our credulity. In another case reported in West Virginia, the eagle, which measured some ten feet across, attacked a railroad worker and was finally killed after a desperate fight. On writing to the man, whose name and address were given in the paper, it was found that he had killed an eagle, but the account of the great size and savage attack were pure fiction.

As our magnificent national bird is largely a fish-eater and scavenger it is utterly inexcusable that it should be exterminated, and it is the writer's opinion that the golden eagle also should be protected in practically all parts of its range.

According to F. H. Dale[1] "The Golden Eagles are highly beneficial to agriculture in the sum-total of their activities and should not be destroyed as a species, although occasional individuals may require destruction because of lamb-killing habits."

In the same article Dale quotes a letter from the sporting page of the *San Francisco Chronicle* as follows:

> . . . I use my airplane, which is a three-place biplane. I remove the left door so the gunner can shoot to the left. I have ribbons taped to the wires so they will not shoot into the propeller. . . . At times I am able to fly within 50 feet of the bird by getting behind and slightly over it. We are permitted to kill golden eagles but not the bald variety. . . . This is something new and I am in the business of taking passenger-hunters out. In an hour's time I usually cover 70 or 80 miles of territory. . . .

What chance does the eagle have in such a case? Dale says: "The five eagles seen by me, and said to have been killed or crippled from an airplane were all bald eagles"—another case where the protection of one species does little good when a similar species is unprotected.

An interesting pamphlet, "Save the Bald Eagle," is one of the many being distributed by the Emergency Conservation Committee, 734 Lexington Avenue, New York City.

Suppose it be assumed that the smaller predators, the "vermin" of the sportsmen, do destroy considerable numbers of birds that are desired as game. Does the destruction of these predators have a beneficial effect in increasing the numbers of game? The results of the investigations of Dr. Paul L. Errington and others in Wisconsin and Iowa on the quail population seem to give a negative answer to this question.

These field experiments were carried on during the years 1929 to 1934. It seemed to be shown that the carrying capacity of bob-whites for a given area depended upon the winter carrying capacity of that area. If there were too many birds at the end of the breeding season they were reduced to a fairly definite number by the end of the winter, depending largely on the food cover and escape cover of the area, with little apparent relationship to the number of predators. Errington says:[2]

> I do not intend any statement of mine to mean that under no circumstances could predators have any influence upon quail populations. I make no pretense of knowing all there is to

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[1] *The Condor*, September–October, 1936.

[2] *American Forests*, January, 1935.

> know about the matter. Natural relationships are too complex to permit of any hard and fast generalities. But the data from five years work make it apparent, nevertheless, that the influence which differences in predator numbers may have had on the survival of quail populations studied has been so slight as to be unmeasurable. Certainly the importance of predator control in the management of the northern bob-white has been grossly overestimated, while a deplorable lack of attention has been given the manipulation of food, cover, and covey ranges. Indeed the public tendency has been to emphasize the negligible predator factor to the virtual exclusion of management measures that really count. . . .
>
> Man himself, by means of his intelligence and modern hunting equipment, is about the only predator of which I know efficient enough to reduce bob-white populations much below the normal winter carrying capacity of the land.

An aspect of "vermin" destruction that is appreciated by but few persons other than trained naturalists is the possibility of upsetting the so-called "balance of nature" or the "web of life." As Grinnell says:[3]

> The relationships which have been set up through the ages between wild birds, mammals, and plants, in fact between all forms of life, can not be disturbed unless we are willing to accept the consequences—and these may be exceedingly serious for us.

The possible results of the introduction of new species into a given territory are more generally appreciated than the destruction of an indigenous species.

J. R. Kinghorn, in a presidential address, "Faunal Problems," published in the *Australian Zoologist*, Volume V, Part 3, calls attention to the problem, among others, of the well-known rabbit pest of that country. Introduced by Governor King in 1791, the rabbits are now so numerous that it has been estimated that if they could be eradicated, "New South Wales alone could carry another 10,000,000 sheep." Although such a pest to agriculture there is another side to this question, as the pelts of rabbits were exported in 1926 to the value of over 4,000,000 pounds sterling and the carcasses brought in 3,000,000 pounds; about $35,000,000 is a considerable income to be derived from a waste product.

Those who are advocating the extermination of our interesting pelicans because of their supposed destruction of fish might note a similar case quoted from Sir Arthur Thompson in Publication No. 1, page 16, of the Federation of Ontario Naturalists.

> There is an Australian story that reads as if written for man's instruction. On certain Murray River swamps several species of cormorants used to swarm in thousands, but ruthless massacres, based on the supposition that cormorants were spoiling the fishing, reduced them to hundreds. But the fishing did not improve; it grew worse. It was then discovered that the cormorants fed largely upon crabs, eels, and some other creatures which devour the spawn and fry of the desirable fishes. Thus the ignorant massacre of the cormorants made for the impoverishment, not for the improvement of the fishing. The obvious moral is that man should get at the facts of the web of life before, not after, he has recourse to drastic measures of interference.

Now, the question is, What can be done to stop the slaughter? Perhaps the public will have to be educated until it can force the passage of necessary legislation. The most logical agents to secure this legislation would seem, perhaps, to be the state conservation commission and similar groups under other names.

But alas, of the twenty-seven commissions that replied, out of 36 that were questioned, nineteen expressed themselves in favor of "vermin" control campaigns.

According to a U. S. Biological Survey Bulletin, issued in 1935, 28 states pay bounties on certain birds or mammals or on both. One state, this year, will pay $40 to each group that kills more than a certain number of animals in its campaign. Various individuals and organizations are waging a strong war against this evil.

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[3] SCIENTIFIC MONTHLY, pp. 533–556, December, 1935.

Conservation has suffered an irreparable loss in the recent death of Dr. William T. Hornaday.

The Emergency Conservation Committee deserves the support of all conservationists. That excellent popular journal, *Nature Magazine,* is a tireless and fearless advocate of conservation. The Federation of Woman's Clubs might be, perhaps is, a mighty force to secure legislation.

The American Society of Mammalogists, a few years ago, appointed a Special Committee on Predatory Mammal Control, with the well-known mammalogist, H. E. Anthony, as chairman. After careful investigation the committee made its report and made the following recommendations, which were adopted:

(1) That the Society strongly urges the Biological Survey that the use of poison as a control measure against predatory mammals be drastically curtailed, with the view of complete suspension of poisoning as soon as reasonably possible.

(2) That the Society deplores the propaganda of the Survey which is designed to unduly blacken the character of certain species of predatory mammals, giving only part of the facts and withholding the rest, propaganda which is educating the public to advocate destruction of wild life.

(3) That the Society asserts the claim of the great nature-loving public to a voice in the administration of our wild-life resources, and challenges the right of a federal organization, such as the Biological Survey, to consider only the interests of a very small minority, the livestock interests.

The attitude of trained naturalists towards wild-life destruction is seen in the following protest, issued, about two years ago, and signed by the heads of many of our greatest natural history institutions:

A PROTEST

WE, the undersigned, having taken cognizance of the fact that conditions operating for the destruction of American wild life are becoming increasingly intolerable, view with the gravest concern the present wholesale and largely indiscriminate use of poison at the hands of paid, and frequently irresponsible hunters, whereby it appears that the very existence of all carnivorous mammals, including those valuable species which constitute the chief check upon injurious rodents and are a vital element of our fauna, is imminently threatened over large areas. We therefore earnestly petition that this extensive program of poisoning operations be immediately abandoned, and that no extensive and general destruction of any form of wild life, by trapping or other means, be permitted in the name of expediency, without this course having first been abundantly proved as justifiable from an economic view-point by having made a thorough investigation of the food habits of the species concerned, prosecuted by disinterested and properly qualified parties

COAL-TAR CONTEMPLATIONS

By Dr. VICTOR ROBINSON

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CHEMICAL processes were known to the pre-Greek nations before Empedocles speculated on the elements and Democritus defined the atom. There is no question of the lineage of an art once called the holy art, the hidden art, the black art, the Egyptian art. The more we realize the antiquity of chemistry, the stranger it appears that chemical education is an idea of modern times. There was no school of chemistry until a youth of twenty-one opened his laboratory to students at Giessen: the innovator was Liebig and the date 1824. Prior to that time, the general student could enter the chemical laboratory only through the door of an apothecary-shop. Liebig later traveled through England, and as he found no chemical laboratories for public instruction, he informed his friend Wöhler: "England is not the home of science."

England waited until 1845 before establishing, under the tutelage of Hofmann, its first college of chemistry. If we wonder how it happened that the German chemist, August Wilhelm von Hofmann, appropriately born in Giessen and trained by Liebig himself, should be teaching in London instead of Bonn or Berlin, it must be remembered that the Greeks were wise in exalting chance to a divinity. Hofmann, whose discovery of formaldehyde was only an incident in a career of splendor, remained nearly twenty years in London because Queen Victoria happened to love her German cousin. Prince Albert, particularly interested in the application of science to industry, persuaded Hofmann to undertake a perilous experiment: to give up the work that lay before him and build a college of chemistry on foreign soil. Not until Eberth's bacillus removed the prince-consort from the scene, did Hofmann return to his fatherland.

Hofmann's initial research, carried on in the laboratory of Liebig, was on coal-tar: after discovering the nature of aniline, which ever afterwards he spoke of as his first love, he succeeded in finding in coal-tar the hydrocarbon that Faraday originally found in oil gas—the mystic fluid, benzene. Among those who heard Hofmann expound coal-tar chemistry was a rector's son, Charles Blachford Mansfield. Ill health delayed his formal education, and the pupil was only one year younger than the teacher. Mansfield became absorbed in the fractionation of distillates, and devised the apparatus and method by which benzene could be recovered from coal-tar. In Hofmann's laboratory, Mansfield thus laid the foundation of the coal-tar industry, though years passed before benzene became commercially available. Mansfield's pioneer monograph on "Aeral Navigation," his brilliant letters from Paraguay and Brazil and his theory of salts, all presaged an unusual career—his Portuguese translator wrote of him as "a great soul stirred by mighty conceptions and the love of mankind"—but the benzene which Mansfield liberated from its prison proved his Frankenstein. Before his thirty-sixth birthday, preparing samples of benzene for the Paris Exhibition of 1855, he saved a building from destruction by running outside with a blazing still in his hands. Mansfield was fatally burned and died in Middlesex Hospital.

There was mourning in Hofmann's laboratory, but work must go on. One year after Mansfield's tragic end, the laboratory was alive with excitement over another pupil, William Henry

Perkin. Learning from his teacher that a basic nitrogenous substance in coal-tar is also the parent substance of alkaloids, young Perkin spent the Easter vacation of 1856 in his amateur laboratory at home, trying to make artificial quinine. (It was an audacious thought, for a generation was to pass before Albert Ladenburg built up conine—the first synthesis of an alkaloid—while the synthesis of quinine has not yet been achieved). Perkin's experiments produced nothing until he treated Hofmann's beloved aniline with bichromate of potash and sulfuric acid. Then the fortunate youth saw before him a darkish precipitate which yielded him a dye. It was Perkin's Purple, subsequently known as Aniline Purple and Tyrian Purple—a modern chemical link with ancient Phoenicia—and now called by the French name of mauve or mauvein. It was the first of the aniline dyes to be discovered, it was the definite creation of the coal-tar color industry.

Perkin bade farewell to the college of chemistry, took out a patent and with the aid of his family erected a factory at Greenford Green, near Harrow, to color the textiles of the world. It adds considerably to the interest of the situation to recall that this new captain of industry, who revolutionized the dye-vats of civilization, was a boy of eighteen. The life of Perkin was indeed a succession of triumphs. Nature placed fragrant coumarin in the tonka bean, in sweet woodruff and in yellow melilot, but Perkin prepared it chemically, the first artificial perfume. Cloth dyed with madder was wrapped around Egyptian mummies, and in the days of Herodotus the cloaks of Libyan women were colored with madder. In later times, hundreds of thousands of acres, stretching from southern France eastward toward Arabia, were devoted to the cultivation of the madder plant. The factory ruined these fields when alizarin, the red dye of the madder root, was prepared from coal-tar by Perkin. In his mid-thirties, at a time when most men are fighting for a foothold in business, Perkin retired from manufacture to pursue his researches without interruption. He then gave to organic chemistry the method of condensation of aldehydes with fatty acids —Perkin's reaction; and in physical chemistry he demonstrated the relationship between magnetic polarization and chemical constitution—Perkin's law.

Elected a fellow of the Royal Society in his twenties, president of various technical associations, the recipient of complimentary doctorates from universities and of the Davy medal and the Albert medal, Perkin was accustomed to honors, yet the international celebration, in the summer of 1906, must have stirred even that much-honored man. Perkin was now a bearded patriarch, the father of four daughters and three sons, and each of the sons was a distinguished chemist. On this jubilee of his discovery of the first aniline dye, nation and nation testified its esteem of Perkin. His country bestowed knighthood upon him; France gave him the Lavoisier medal; Germany —in the person of Emil Fischer—gave him the Hofmann medal; the United States founded the Perkin medal for American chemists, and he received diplomas sufficient to cover his largest wall. The following year he died, and the public has not yet learned that this man was one of the moving forces of modernity.

Queen Victoria's husband, a victim of typhoid fever at forty-two, lay sleeping in his magnificent mausoleum, but the sagacity of Prince Albert had long been vindicated, for Hofmann's laboratory was the ovum from which developed the coal-tar industry. Chemical industry is not new: its origin is found in the blowpipes of the Egyptians, the dyeing-vats of the Tyrians, the glass-furnaces of the Assyrians, the kilns of the Babylonians, the petroleum-fires that burned on the altars of the Hebrews. The coal-tar industry is not the beginning, it is the consummation of centuries of chemistry. Coal-tar, dark, thickish, neither a liquid nor quite a solid, a useless residue clogging the pipes in the making of illuminating gas, has become, in the Perkin era, a central item in the wealth of nations.

Nature has filled the tar-barrel with a lavish hand, and it has brought color and comfort to mankind. It is the philosopher's egg, the elixir of life of the modern alchemist. A remarkable Materia Medica could be compiled, limited entirely to coal-tar products. The rejected nuisance, the despised by-product of the past, is nature's own laboratory, whose magic alembic distills fluids and vapors and scales and crystals for the alleviation of suffering. From coal-tar and allied substances are derived countless synthetics which have replaced the herbs of our forefathers. Among these remedies are the antiseptics, phenol, cresol, resorcin; the local anesthetics, alypin, novocaine, stovaine; the hypnotics, veronal, adalin, luminal; such antipyretics as pyramidon, acetanilid and that household fetich, aspirin. Out of the tar barrel, the exhaustless hope-chest of science, have come such diverse medicinals as saccharin, the permissible sugar of the diabetic; atoxyl for sleeping sickness; and salvarsan and neo-salvarsan for the conquest of syphilis.

Parasiticides and perfumes, fuels and photographic supplies, the asphalt of the pavement and the varnish on the roof, are all born in the deep womb of coal-tar. Cradled in England, the coal-tar industry reached maturity in Germany. Coal-tar industrialism has grown too big for ethical control. Worship of the chemical god was one of the economic factors of the world war. Perhaps it is time for the generation that has grown up in the shadow of the machine age to heed the words of Aristotle. "Industrial work," said Aristotle, "tends to lower the standard of thought." In our era it has lowered the entire standard of human behavior. Every discovery of science is now tested in the counting-house of commerce. It is only poetic justice that in the world war, coal-tar which gave man the healing antiseptics, chloramine-T and dichloramine-T, to soothe his wounds, also gave him trinitrotoluene—the dreaded explosive, T.N.T. —and poison gas. Over the fields where man has shed the blood of man, forever sounds the challenge: "After two thousand years of mass, have we got as far as poison-gas?"

On the eve of the centenary of Perkin's birth, one is reminded of the Enoch Saga. In the Ethiopic Book of Enoth it is written that the angels who visited our world were earth-bound by the beauty of woman; instead of returning to heaven, as all good angels should, they married the daughters of earth, and in gratitude for their favors, revealed to their offspring, who were giants, the worth of the metals within the earth and the healing powers of the herbs that grew upon the earth. That this knowledge should not be lost, the fallen angels inscribed their teachings in a book called *Chema,* from which is derived *Chemia.* It is an ill-made legend, compounded from the sixth chapter of Genesis—there are later accretions by Zosimus of Panapolis, the first of the Greek alchemists—but it remains of interest as one of the fabled origins of chemistry. In the Slavonic Book of Enoch it is written that man was created with free will and shown the way of light and of darkness: he turned from the light and lost himself in the darkness. In every generation man stands at these crossroads, facing the same decision. To-day, armed with the new chemistry, so potent for good and for ill, he must choose again. Will he again pass through the gates of greed to follow the old road of racial hatred and war, or will he emerge in the light on the highway of human brotherhood? To-morrow's children will know the answer.

A FORECAST OF TECHNOLOGICAL EDUCATION

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As a form of intellectual effort, forecasting is more notable for its ability to survive failures than for its successes. It flourished with the soothsayers of Egypt and the oracles of Greece; it lost none of its vogue in the hands of the astrologers of the Middle Ages; it is practised to-day by tipsters, weather prophets, investment counselors and a host of similar services.

Wishful thinking and the fact that "hope springs eternal in the human breast" account in part for the hold that forecasters have on us, as does also the human frailty of trying to shift responsibility by making decisions. More fundamental, however, is the fact that almost every rational action has to be based upon some sort of forecast of its future results. Rational human beings, therefore, must of necessity be forecasters.

The progress of civilization may be measured by the trend from superstition to science in forecasting, but this trend has been immensely more rapid in some fields than others. Astronomers can predict an eclipse with stop-watch accuracy a century in advance; psychologists have made at least some progress in ability to forecast probable success in different occupations by measuring students' aptitudes; medical men are as yet powerless to foretell when or where the next epidemic of infantile paralysis will break out. All grades of forecasting, from hocus-pocus and racket to art and science, coexist as part of man's struggle for a more satisfying life.

Having thus defined the field and exposed the uncertainties of forecasting, I immediately confess that my present excursion into this realm lies somewhere in the scale between racket and science, at about the point usually described as "hunch." My logic may be faulty or unforeseen conditions may arise to change the picture, but, as I see it, technological education in the future will show the following characteristics:

(1) The importance of technological education will continually increase. This appears to be the sure result of three factors: first, the increasing competition which is forced upon individuals and organizations as the opportunity for free expansion into the unoccupied frontiers of the West disappears, second, the necessity of using and husbanding our natural resources more wisely as these become less and less available for easy and wasteful exploitation; third, the increasing applications of science to minister to human needs and desires, which are so important a feature of our so-called rising standard of living.

(2) There will be increasing differentiation between technological and technical training, *i.e.*, between the engineering school and the trade school. The field is rapidly becoming too complex to be included in one and the same curriculum, and the school which attempts to straddle both will succeed in neither.

(3) Large industrial units or associations will increasingly establish their own trade schools to train expert technicians for their own special purposes. Private or public technical schools will similarly supply the general needs of the surrounding industrial communities for skilled mechanics, lithographers, textile workers, electricians, draughtsmen, and the like.

This system will practically replace the older apprentice system which, for better or worse, is rapidly disappearing.

(4) Undergraduate curriculums in technological schools will increasingly avoid specialization except in rather general fields, and will devote increasing attention to physics, chemistry, and the general principles and methods of engineering, with supplementary education in social science and training in the art of exposition. Such broad and basic training is needed to give the vision and adaptability required for positions of responsibility in a world of activities which are increasingly dependent on applications of science in new and varied ways.

(5) As a corollary, the increasing need for many technological specialists will be met by the graduate curriculums, and we may expect a continuation of the recently growing emphasis on graduate study.

(6) We will see increasing differentiation in scope and more logical adaption to environment in our colleges and universities. This will be forced upon them by competition or achieved voluntarily after wise appraisal of opportunities. Most of our present colleges were founded in the era of horse and buggy or limited rail transportation. Most of them were intended to minister to local educational needs. As transportation becomes faster and easier, and the people become more travel minded, why should an ambitious young man try to secure a specialized training for a profession at Podunk College, when a few hours of travel will give him the superior education of a great institution?

Obviously this tendency is more pronounced in the higher grades of the educational system, such as the professional and graduate schools. We will, therefore, see many a smaller or less favorably situated institution drop its ambitious attempts to encompass the whole field of education and concentrate its resources to do the best possible job as an undergraduate or a junior college, perhaps retaining some special field of local significance. At the same time, the higher ranges of education will be concentrated in the most favorably situated institutions. Even among these, the selective process will operate, and we will see a few of them emerge as superprofessional schools, with the graduate aspect strongly emphasized.

(7) Research will become a continually more important activity in the leading technological schools. Two important factors conspire to bring this about, one pedagogical and the other social.

As to the first of these, it will suffice to remark that research, *viz.*, investigation and report of some problem conducted intensively and relatively independently by a student, aided by all the resources of library, laboratory and consultation which he can marshal, supplies a test and training for an important element of his future career, which are not afforded by ordinary classroom or laboratory methods of instruction. Research, as for graduation theses, is a more expensive type of training than lecture, quiz and laboratory exercise; it is far more difficult to handle properly by the faculty, but if so handled it is likely to be fascinating to the student. I believe research to be capable of great development as a feature of education, both graduate and undergraduate, and those schools which are able to handle it adequately will take a predominating place in the educational world.

The social basis for research in educational institutions lies in the combination of urgent public need for research and unique opportunities for performing some kinds of research in educational institutions. Such institutions have extensive and varied laboratory equipment, large staffs in many related fields of science and art, and a great supply of young men available as students or apprentices to work under expert guidance. There is thus a dovetailing of interests and facilities between education and research, which is mutually most favorable.

Public welfare calls for research from a multitude of angles; new developments in industry, public health, agriculture and all technical fields depend on progress in pure science and development of new materials, processes and methods. While industrial organizations can profitably conduct research on problems related to their specific interests, and governmental agencies can properly undertake research in specific fields of wide public interest, none of these is justified or equipped, as are the educational institutions, to engage in the general advancement of knowledge on which all depend in the last analysis.

For such reasons I look for an increased activity in research in the technological schools and for their support by the public in this activity. Such support will come in a variety of ways: by gifts from public-spirited benefactors; by contracts from industrial associations for investigation and report on fundamental or obscure problems of general interest to the associations; by grants directly by the government in support of important scientific programs. The first of these is one of the finest outgrowths of the American capitalistic system; the last two are logical ways in which the benefits of research, specifically rather unpredictable but of unquestioned value in the aggregate, may be supported by the group for the general good. Recent practices of certain governmental bureaus and provisions in Congressional bills indicate a strong trend toward recognition of research in educational institutions—even outside the land-grant group—as a proper and desirable expenditure of public money.

(8) Finally comes the question: "Will increasing taxation and other methods of forcibly distributing wealth so cripple private philanthropy in this country as to sound the death knell of the privately supported educational institutions, leaving all education in the hands of the state?" Inflation and taxation in an essentially socialistic state could accomplish this. If it should happen, education would be a major loser in the general catastrophe. Fully admitting the splendid work of many state-supported universities and their essential contribution to our national life, it is, nevertheless, the independent institutions which have set the pace and maintained the intellectual integrity and freedom of our entire educational system. Lose them, and the whole structure is freely exposed to the danger of political manipulation and domination.

Private institutions can pay their key men salaries larger than those of the average voter or political office holder, can undertake intellectual projects of no obvious practical value, can report facts or announce theories without thought of the political strife of the moment. Such things are not so easy in a state-controlled school, and would be vastly less easy if the bulwark of tradition and example of the private institutions were destroyed. State institutions suffer under still other handicaps: It is easier to get appropriations for buildings, which show, than for the staff, which really makes the institution; the institutions tend to become pawns in the game of taxation and budgets, with the staffs playing the rôle of very nervous onlookers and the presidents forced to mingle lobbying with educational administration; the pressure to expand activities and serve all groups works against concentration on essentials and maintenance of high standards. Elimination of independent educational institutions would, therefore, not only sacrifice educational leadership, but would enormously increase the difficulties in spite of which the state institutions are now performing their functions so splendidly.

I do not believe that the basic good sense of the American people will permit these things to happen. I believe that our tradition of freedom, initiative and individual rights will continue to develop men and women who will acquire wealth and who will wish to use it for outstanding benefits to the general social group, in which education is an important element. I do believe that the economic trends are making the path of the private institutions more difficult and that some of them will succumb. The trend, I believe, will be for state institutions to assume more of the burden of ordinary education, expanding from the public-school field into the junior-college field, thus substituting education in place of unemployment.

CONCLUSION

If these forecasts do not entirely miss the mark, they offer both encouragement and guidance in our efforts to make the privately controlled institutions of technology of the future preëminently strong and serviceable institutions. Above all, they indicate that the *criterion for survival of a private institution will be that it offers a quality of education and public service, definitely superior to that obtainable in government-operated institutions.* This is the challenge of the future to those who administer the affairs of private institutions and to those who wish such institutions to endure as vanguard and bulwarks of a free and progressive social order.

PIANO TOUCH

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ONE is tempted to say that touch is the touchiest subject in musical circles, because we are deeply impressed with the enormous possibilities for characterizing musical artistry and expression of musical feeling in terms of this art. The vocabulary descriptive of touch now current is extensive, loose and baffling. Historically, but little effort has been made to aid the student in music by bringing order out of this chaos from a scientific point of view. However, recent scientific approaches to this subject have made progress and give assurance of the possibility of an adequate analysis, description and terminology for many of these phenomena. The best available book on the subject for musicians is the volume by Professor Ortmann, director of the Peabody Conservatory of Music. It is based upon a searching analysis of historical, theoretical and experimental evidences. His principal findings may be summarized as follows:

The pianist has at his direct control only two of the four factors in music; namely, intensity and time. Pitch and timbre are determined primarily by the composer and the instrument.

The pianist can control the intensity only in terms of the velocity of the hammer at the moment at which it leaves the escapement mechanism, and by the action of the pedals.

There are only two significant strokes on the key: the percussion and the nonpercussion. The difference between these is that the former contributes more noise to the piano tone and the latter gives the player better control of the desired intensity.

Aside from the addition of the noise, the player can not modify the quality of the tone by the manner of depressing the key or by manipulations after the key has struck its bed except, perhaps, by a momentary partial key release and immediate key depression, damping the tone somewhat but not entirely.

He can control the time factors which

influence quality only by the action of the dampers either through the keys or the pedals.

In general these facts have been known for a long time by instrument makers and leading musicians. But many musicians have failed to recognize their significance or admit the facts. Indeed, experts in various fields of acoustical science also have questioned the findings enough to justify taking the problem into their laboratories for analysis and verification. However, all the investigators have reached the same conclusion on the above points. Let us examine each of the essential factors in turn.

In so far as it depends upon the stroke of the key, intensity (the physical fact) or loudness (the mental fact) is a function of the velocity of the hammer at the moment that it impinges upon the string After that the tone can be modified only by action of the dampers. The piano action for any key consists of a compound lever system, the purpose of which is to facilitate and control the force of the blow on the string. Let us consider the nature of the blow.

If a ball is placed on the inner end of a cleared piano key and the key is struck in the usual manner, the ball will fly from the key up against the string. Nothing can influence the velocity or the direction of the ball after it has left the key, and the ball can energize the string only at the moment of impact because, due to resilience of the compressed felt and the throw of the string, it bounds off instantly. The function and action of the hammer is analogous to that of the ball. The velocity of the hammer is determined by the velocity of the escapement lever at the moment the hammer is released for its flight, and the force of the blow is determined by the velocity of the hammer at the moment of impact. From this, several considerations follow:

(1) It makes no difference whether the key is struck by an accelerating, retarding, even, or any form of irregular movement; the only significant thing the player controls in the stroke is the velocity of the key at the exact moment that it throws off the hammer.

This easily observed physical fact has profound significance in the theory of playing, hearing, enjoyment and critical judgments about music. The economic aspect is not to be ignored when we consider what money is spent in trying to teach pupils to do something that can not be done. It takes away a great deal of glamor and grace of mannerisms in the mode of depression of the key. It reduces touch to the fundamental factor of intensity.

This should in no way detract from the resourcefulness of the instrument and the opportunity for individual expression or the indirect effects of intensity, which are legion On the other hand, it clarifies, glorifies and reveals the extraordinary refinement that is necessary in this artistic touch. The elaborate care taken in the development of form, weight, pressure and rate of arm, wrist and finger movements is fully justified in so far as it results in a refined control of the intensity of the tone but not for any independent change in tone quality.

(2) The hammer is released just a trifle before the key reaches its bed. Like the ball, it has only one form of contact with the string; namely, an instantaneous impact followed by immediate rebound. The movement of the key can not influence the hammer after it has been released any more than it can influence the flight of the ball after it has been thrown off. Therefore no amount of waggling, vibrating, rocking or caressing of the key after it has once hit bottom can modify the action upon the string. The only way in which the key can further affect the string is by a new stroke of the hammer. This can easily be verified by manipulating a key near its bed and looking at the action of the hammer.

Probably the only exception to this

statement is the rare or doubtful possibility that a partial release of the escapement mechanism may re-engage the hammer stem so that the hammer may again be thrown against the string and a partial damping may result. However, even if physically possible, this is merely a stunt and is not attempted by artists under normal conditions of playing. Yet this fallacy plays a rôle in musical circles in at least three important respects. First, whenever this stunt is affected, the observable finger action serves as a suggestion which produces the desired result in the form of an illusion of hearing. Such normal illusions have a very great influence upon musical hearing. Second, in ignorance or defiance of the physical limitations, teachers often attempt to train pupils in the supposed art of this type of finesse. And third, theorists who oppose the limitation of touch to intensity control frequently fall back upon this phenomenon to sustain their claims. However, all well-informed musicians recognize that this feature is not important in their artistic playing. Therefore, we may ignore it in the discussion of the real factors in musical touch.

(3) Indirectly the pianist can produce a great variety of tone qualities, but only by his control of the intensity of the tone. Having imparted a given velocity to the hammer, the pianist is entirely at the mercy of the instrument for the determination of qualitative changes taking place in the tone, except for manipulation of the dampers. The piano is so constructed that it can produce a vast series of tone qualities, each one a function of the intensity of the tone. Each instrument has its own relatively fixed characteristic in this respect. In general, the louder the tone, the richer it will be in quality.

If we represent a series of intensities by the letters a, b, c, d, *etc.*, and the corresponding degrees of richness and other characteristics of the quality by the symbols a′, b′, c′, d′, *etc.*, then whenever a tone of intensity a is sounded, a quality a′ is produced; intensity b for the same tone will always yield a quality b′; intensity c or any other intensity will always yield its corresponding tone quality. It is possible therefore to calibrate any particular piano in this way and to set up a scale of intensities which will yield approximately the corresponding scale of tone qualities. However, the situation is complicated by the fact that each instrument has its own resonance characteristics and responds differently to different chords.

This setting up of a scale of equivalents for intensity and tone quality is just what every pianist has to do empirically. Rarely is it a clearly conscious effort or scale; probably it can best be described as a relationship which he has felt himself into more or less subconsciously.

(4) In 1933 Ghosh demonstrated that within a considerable range of the intensities normally functioning in music, the wave form of the vibrating string and therefore the resulting harmonic constitution remains constant. Thus, within a moderate range of changes in intensity, the player can not modify the quality of the tone as it emerges from the string.

The qualitative changes which come with changing intensity are the result of resonance, reverberation or damping effects of the sounding board and the rest of the piano, the thuds and rattlings on the keys, as well as the acoustical characteristics of the room. The wave emitted by the sounding board and its accessories is very much stronger than the wave emitted from the string, and therefore becomes dominant in hearing. The wave form that impinges upon the ear is an amplification and modification of the wave form emitted by the string. This principle applies to all other musical instruments.

At the present time artists regard inharmonic and percussion accessories to piano response as legitimate and essential contributions to tone quality. Is it possible that this attitude may change? We are facing an era of radical change in the nature of music. It is difficult to predict what will happen to concepts of piano playing. Several factors must be taken into account.

First, the piano of to-day, the manner of its use and the tastes and habits of hearing are determined in large part by the heretofore existing mechanical limitations to construction of the instrument. This piano quality involves a variety of thuds, rattlings, raspings and various other forms of noise which are utilized for musical effect and add pronounced characteristics significantly to the tonal elements, especially in the louder intensities. It is, to a considerable extent, in the impurities of tone that we differentiate instruments.

Second, it is now possible to construct a synthetic-tone instrument in which we may include any desired sound quality, and therefore eliminate any of the present characteristics which may be redundant or undesirable.

Third, in such an instrument, it is now possible to introduce a vast variety of tone qualities which we have not been able to produce with our present instruments. We must, therefore, consider the possibility of thinking of the future of music in terms of instruments in which the characteristics are not due to the limitations in mechanical construction but are the deliberate choice, the result of invention and discovery of entirely new tonal complexes for musical satisfaction.

Fourth, it is a matter of history and psychology that likes and dislikes, tolerance and intolerance, artistic cravings and urges, are matters of development contingent upon the tendency to make the best of what we have, the biological tendency toward new habit formations and the inherent artistic merit in innovations.

These situations the piano shares with all other instruments. Conservatism tells us that there will be no sudden change, but insight into the nature of the situation tells us that the change will be radical, and that it must of necessity be in the interest of higher levels of musical achievement with new problems for the composer, the performer and the listener.

Is it probable that the electrical flute, clarinet, trumpet or violin will introduce new satisfaction in the purity of harmonic factors so that we can dispense with the noises which at the present time give us the characteristics of the instrument? We may venture to answer that these new resources in electrical instruments will vastly enrich our world with harmonic tones and will "chasten" or replace many of our present instruments, but there may always be an artistic demand for inharmonic elements, and other noises and percussion features.

(5) Pianists have fairly clear concepts of characteristics of tone quality, such as harsh, brilliant, mellow, full, singing, round, shrill, dry, metallic, steely, brittle, shallow, poor, ringing, clear, velvety, bell-like, jarring and strident. Ortmann performed an experiment in which a number of distinguished artists participated and were able to produce the qualities just named to their general satisfaction. But a recording device attached to the piano revealed that the only two variables that had been under their control were the velocity of the hammer blow and the action of the dampers which affected the duration and loudness of the tone, and that, whenever qualitative differences were present, they were differences in intensity and time relationships.

(6) The countless varieties of temporal movement are also reduced to the operation of time, with some modification by

intensity. Ortmann performed experiments in which accomplished pianists gave artistic expression to such marks as *accelerando, ritardando, affettuoso, espressive, scherzando, etc.* The recording device on the piano revealed the fact that all these characteristics of musical movement were completely controlled by the two factors, the time relationships and the intensity of the tone.

(7) The pianist can modify quality through controlling the time factor in three ways: the tempo and the temporal aspects of rhythmic features are determined largely by the duration of vibration as determined by the moment of application of the dampers through the release of the key; the vibration may be continued by overholding the notes with the sostenuto pedal.

It is well known that the piano tone fades out rapidly soon after the hammer stroke; but the listening ear tends to ignore this and, instead of hearing tones as having sudden changes in intensity and timbre, tends to hear the initial characteristic of the tone until the next key is struck, in spite of the fact that the physical change in the tone is very radical. For this reason, it seems to make relatively little difference whether a key is held down for the entire time assigned to it in the score. As a matter of fact, the player is often irregular and relatively indifferent in regard to the time for release of the key, especially in rapid movements. He depends on this tendency in hearing to carry over. In musical hearing the effect of overholding the note by pedal is perhaps more evident in its modification of resulting tone quality than in the awareness of the continuation of the note or chord as such.

(8) The most profound change the artist can give to tone quality comes through pedal action. By means of the sostenuto pedal tones may be carried through a series of chords after the respective keys have been released, thus producing great enrichment in the harmony through the gradual overlapping and fading of antecedent tones. Refinement in the use of this medium is an outstanding mark of artistry.

In the use of the una chorda pedal the artist has a choice of striking one, two or three strings. Two effects result. The softer felt tends to dampen partial vibrations of the string and the remaining string or strings vibrate in sympathetic resonance. A combination of such tones obeys precisely the same laws as tones produced without pedal although the basic tone-complex is altered. The action of the soft pedal involves, of course, purely the factor of intensity

(9) The great tonal resources of the piano as an instrument lie in the richness of tone produced by the possibility of playing one or many keys, with or without pedals, and thus utilizing both harmonic and melodic progressions. But these are as a rule set in the score by the composer, and the possibility of legitimately introducing variants and ornaments not so indicated is limited.

(10) It is, of course, recognized that the pianist has many devices for changing the quality of tone by freedom in the use of intensity or in time. For example, tone coloring is a very conspicuous feature in artistic playing, but it ordinarily means that the pianist strikes the notes in the chord with different force and thus can produce varying resonance effects from the same chord. Likewise, there are considerable resources in the variety of uses of the pedals, both as to time and intensity. The pianist has various devices by which he can get sympathetic vibrations and modulate overtones. There are also many ways of enhancing subjective tones which may play an important rôle, clearly modifying the perceived tone quality, and we must not overlook the vast array of illusions which have qualitative significance. Last but not least, there is the power of suggestion.

(11) The artist may legitimately think

and perform with tone quality as his objective, and consciously control his touch in terms of tone quality. Likewise the listener may regard tone quality as the primary factor and think of intensity as a secondary and even unrelated factor. But the fact remains that, in general, the only way in which the pianist can produce qualitative changes is through dynamic and temporal changes, and then only within the limits set by the characteristics of the instrument.

(12) It follows from these considerations that a fairly adequate record of musical performance can be made by recording the velocity of the hammer blow and the action of the dampers. With a given composition and a given instrument of which the characteristics are known, we can describe the essentials of artistic performance on the piano in terms of the artist's command and use of these two factors.

The Iowa piano camera is built on this principle It registers the performance in minute and serviceable detail in a permanent photogram. This can be transcribed into a scientific performance score, in terms of which objective analysis of the tonally significant features of the rendition may be made.

The purpose of this analysis has been to pave the way for a synthesis. In acoustics we have analyzers which may dissect any rich tone into its component partials; conversely, we have synthesizers which can take all known partials of any rich tone and reconstruct the original single sound wave. On this analogy it is here suggested that the principle which justifies our reducing a rendition to its two operating media justifies our assuming that, by reversing the process, we may derive all the salient elements in the performance from an adequate record of these two media. Such matters as phrasing, personal interpretation, the principles of art involved, errors, idiosyncrasies and exhibitions of skill are embodied in such a piano camera record.

FOR SCIENCE

By Dr. A. S. PEARSE

PROFESSOR OF ZOOLOGY, DUKE UNIVERSITY

We live, then, in an age of grave social disorder and threatening chaos; and it is in the main due to science.—*McDougall*, 1935.

Scientific civilization has destroyed the world of the soul. . . . Civilization has created new stimuli against which we have no defense.—*Carrel*, 1935.

THE rewards of success are power, position and hard work; not affluence and ease, as the unsuccessful believe. The penalties of success are jealousy and responsibility. The tycoons of the earth are always the subjects of green-eyed envy. They must care for the so-called unfortunate and tell them what to do. They are blamed for hard times, plagues, famines, hurricanes and other "acts of God."

During the past century science has been successful. It has made the world more or less cosmopolitan, safe, comfortable, healthful, tolerant, honest, sensible and understanding. Naturally it is blamed by non-scientists for the troubles of society. Critics of science gleefully point out that scientific theories grow into dogmas which impede the progress of civilization as much as those of theologians, politicians or economists; though scientists have labored for generations to explain natural phenomena, the world is still full of mysteries; though knowledge has increased enormously, man is still wicked. Perhaps the worst sin that science has perpetrated is the giving to civilized man comfort, convenience and leisure, so that he does not have to think daily about how he is going to live through. Science has come, the good old days are gone forever; man has not only become soft and degenerate, but remains sinful.

As Shaw says in his introduction to Saint Joan, "Men fear what they do not understand." The writer begs leave, as a scientist, to say a few words for science and will attempt to give some idea of what science stands for and what it is. "The laboratories have conquered, but their triumphs are sealed within their walls."[1] The first author quoted at the head of this essay in a recent book[2] states that science is mechanism, and that mechanism is anti-religious. He then skilfully and astutely destroys his straw man. Of course almost any fellow on the street knows that scientists have very diverse views on religion. It is a mistake to attempt to raise the old issue between science and religion; alive in the days of Spencer and Huxley but now dead. Most scientists respect religion and appreciate what it has done for man. Today thoughtful theologians do not blame science for the troubles of the world. An everyday man is quite satisfied to enjoy the benefits of religion and science without worrying much about either. A few agitators continually shake bugaboos before the public and thus magnify their own importance. Some of these are wild enthusiasts; some are just gossips.

Dr. Carrel[3] says that science has "destroyed the world of soul." This is true in so far as "the scientific method" has made people more sensible and critical of archaic, primitive and naive notions of souls, but it has by no means done away with belief in souls and God, even among scientists. Perhaps the clearest discussion of the relations between science and metaphysics has been presented by Bergson.[4] He points out clearly that science can never do anything but weigh and measure. All a scientist can ever hope to do is answer such questions as how long?, how fast?, how wide? and how much? In addition to knowledge gained by weighing and measuring man may know other things, and these Bergson groups under intuitive knowledge. The crux of the matter is, are there things that can not be weighed and measured? Bergson, most theologues and many scientists believe that there are.

Theoretically science can do no harm. Its sole purpose is to learn the truth about natural phenomena, and truth should hurt no one. Unfortunately scientists are human. They are sometimes just as bigoted and partisan as other men. Some scientists are capable of concealing truth or of telling half truths to help their cause. Some have used discoveries to injure their fellows. But there is nothing inherent in science, its methods or its teachings that should make men wicked. If a man has scientific spirit, he is brave in the defense of truth, but humble before the mysteries of nature. A scientist will always respect evidence more than authority. If he is also a gentleman, he will be open-minded, tolerant, critical but kindly, courageous but cautious. He will perhaps be characteristically methodical, painstaking, accurate, persevering and modest. Such a man, if he is in the least worthy, will not waste his time asserting that religion or other matters about which he knows little or nothing are evil or worthless. He will attend to his own business.

Science has not changed the nature of men or of their societies. It has given opportunities, and men have chosen to use these to make themselves better or worse. The false assumption on the part of critics is that a scientific discovery should mean progress for society. The radio gives man unusual ability to communicate over great distances. It may be used to give notice of storms and to keep ships on their courses through dense fogs, and thus benefit man; but it is also used to send out misinformation (Zion City informs listeners that the earth is flat) or to spread selfish propaganda.

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[1] O. Riddle, *Science*, 83: 69–74, 1936.

[2] "Religion and the Science of Life." Durham, N. C. xv + 263 pp.

[3] "Man, the Unknown." N. Y. xvii + 346 pp.

[4] H. Bergson, "An Introduction to Metaphysics." N. Y. iv + 92 pp. 1912.

It is not the business of science to make men good. Incidentally scientific methods of thought may tend to make men more sensible and honest with themselves. But through all time to come men must as individuals or groups struggle toward idealism along paths that their time and social positions make possible. "Human beings are much alike over time and space. For many thousands of years man has been substantially the same kind of physical being as he is to-day. . . . The simplest form of all societal institutions is custom. . . . Nowhere is real knowledge and science so little in intelligent demand as in the societal realm, for the latter is self-sown to whims and dreams of all varieties. . . . There is one common misconception about evolution, that it means progress. It means adjustment only."[5]

A man must adjust himself to society in the particular time and place in which he happens to be situated. Some independent spirits resent the daily formal observances that civilization exacts and revolt, in words or deeds. The tiresome routine of formal life tends to fill any man with ennui. But man, or society as a whole, does not advance by throwing away established customs and starting anew. Accepted ways of doing things may appear to be silly in the light of pure reason; established notions of right and wrong may not be sensible, but must be observed if one is to be a normal, accepted member of society. A professor must wear a necktie when he appears before his class, but he does not dare to appear with a creation about his neck that on a student would merely be looked upon as "snappy."

Science is a product of modern civilization. It has been created by sweating, thoughtful men—men like ourselves. Scientists such as Pasteur worked to make nature better serve man; those like Darwin have labored because they felt the urge to drive back the frontiers of ignorance. For such men science was noble and ennobling. Along with the uplifters there are always scientific quacks, charlatans, politicians and lately racketeers. Men are just human beings, and will be as long as civilization lasts. Science is truth, but its applications are what men make them.

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[5] A. G. Keller, "Societal Evolution. The Evolution of Man." New Haven. 126–151 pp. 1922.

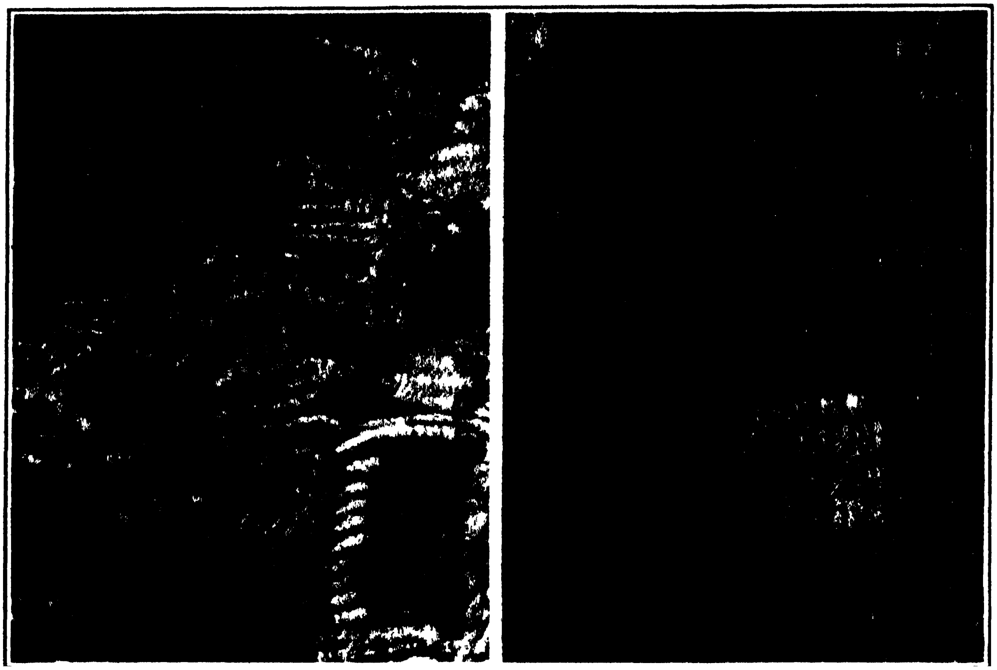
NEW LAMPS FOR OLD IN TEXTILE TECHNOLOGY

By E. R. SCHWARZ

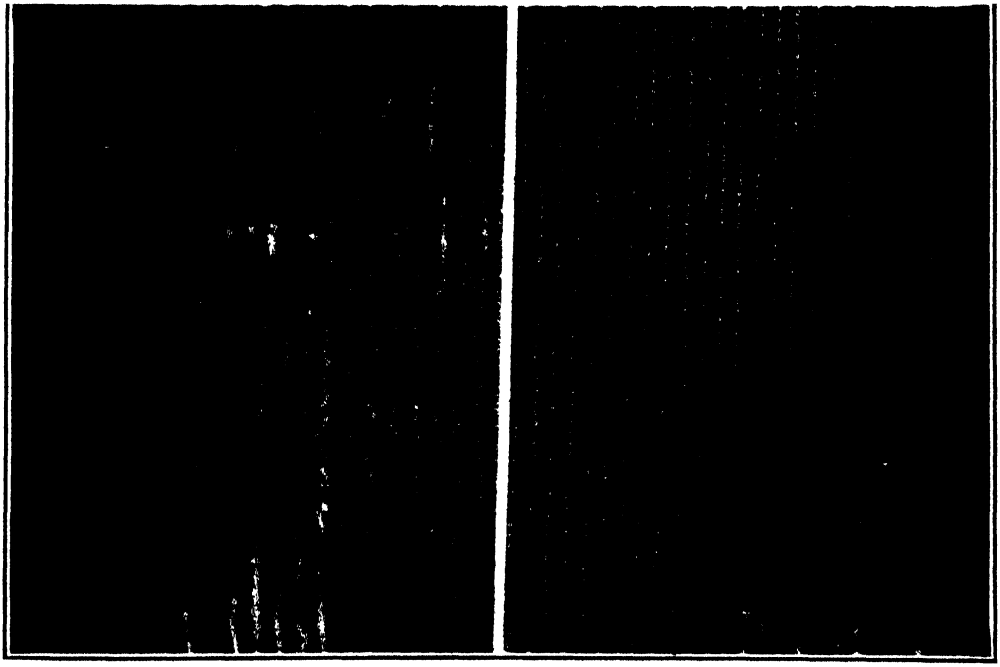
ASSOCIATE PROFESSOR OF TEXTILE ENGINEERING, IN CHARGE OF TEXTILE RESEARCH, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

BOTH physics and chemistry are in the last analysis simply concerned with forms of energy and the manifestations in which these forms are combined and displayed. Probably no branch of technology, therefore, can be anything but a combination of these two fundamental sciences. Nor is textile technology any exception. Even without recognition of the fact in the earlier days of the textile industry, nevertheless physics, chemistry, biology and mathematics joined hands to increase and clarify man's knowledge of the fibers which for uncounted centuries had been and still are the raw materials for yarn and fabric. His knowledge, however, became more and more definite and increasingly fruitful, so that while he was not able to do more than but a little toward controlling the uniformity and desirability of the natural fibers which he used, he was eventually able to produce usable synthetic filaments. Yet none of them can be considered substitutes for the natural fibers in the sense of duplication of properties, as we shall see. Animals must still be depended upon to produce wool. Plants are still unique producers of cotton, flax, hemp and jute. Insects are still the silk producers. The future will be satisfactorily prolific for the textile technologist only as the biologist becomes more intimately and exactly acquainted with the nature and processes of life and with the natural synthesis of fibers. Progress will be satisfactory only when the chemist understands clearly the nature of the forces which bind the atoms into molecules and the molecules into chains. Textiles will be the richer—as will science itself—when the physicist can understand the nature of the forces which stabilize the atom. Expression of the laws which will be found to govern these manifestations of energy must be formulated and made workable by the mathematician.

To say that the future of the textile industry rests in the hands of the atom splitter is not to speak utter fantasy. There was a time when the ultimate was expressed by the man who spoke of "splitting hairs." Nowadays the textile microscopist literally splits hairs—and finer structures—as a matter of course. And as perfection of technique allows him to continue along the path of decreasing magnitudes he feels the urge, as one man put it, to unscrew the inscrutable. He is continually recognizing the fact that everything according to the modern physics and chemistry is in the last analysis a more or less complex association of forms of energy. It seems logical, therefore, to employ certain forms of energy which are fairly well understood and controllable for the attack upon the details of fiber structure. The word "attack" is purposely used as being descriptive of the work. The textile technologist literally bombards the atomic structure of the fiber with a hail of machine gun bullets in the form of x-rays. He lays down a barrage of heavier missiles from his mobile artillery consisting of ultra-violet lamps. With his siege guns composed of polarizing microscopes he batters down the last defenses offered by the fibrils, which are



EXAMPLES OF TAPESTRY TYPE OF WEAVE
Ancient Peruvian fabrics from M D C Crawford Collection



—Crawford Collection and M I T

LEFT, OLD PERUVIAN CORD WEAVE, *RIGHT*, MODERN CORD WEAVE the smallest visible units in the fiber. The chemist sets to work sapping and mining to plant a high explosive in the form of swelling and disintegrating solutions so that the fiber will be actually blown up And, strange though it may seem, the microscopist is even engaged in raining incendiary bombs on fibers by means of a hot stage used with the microscope in order that he may study the charred ruins to determine the nature of the inorganic skeleton remaining.

Just as steel is thoroughly tested for its physical and chemical properties before the construction of a machine, bridge or building, so the textile technologist determines the strength, stretch, rigidity and many other properties of yarn and fiber later to be fashioned into fabric. The study is fascinating, for here is a material—simple cloth, if you will—which is composed of filaments each as strong for its cross section as steel, yet producing a structure which is amazingly flexible. For uncounted generations man has adorned himself and his surroundings with more and more gorgeous, more and more cleverly contrived tissues. Not only may the degree of civilization of nations past and present be measured by the kind of buildings which they erected but by the nature and excellence of their fabrics. As the spinning and weaving of textiles was probably the oldest art known to man, far antedating the working of metals, the study of ancient fabrics is an interesting one for the archeologist. Where and how did the fashioning of leno weaves now widely used for draperies and many other purposes originate? How were the lenos of old Peru woven? Was there a connection between the art of tapestry weaving in the old world and in the new? Who originated pattern constructions produced by means of what the modern weaver calls a double fabric? All these questions and many more outline not only a fascinating field for speculation on the part of the archeologist, ethnologist and historian but present a real challenge to the research worker.

Truly there is nothing new under the sun. The insulation of houses with felts of all sorts is supposed to be a recent development, but for centuries the Mongols have lived in felt-insulated yurts. It is not too long a stretch of the imagination to bridge the gap between the felt-roofed cart of Tibet and the felt-insulated top of the latest model sedan The floor of the newest movie theater is covered with chenille fur carpet made in the same way as the Peruvian pile constructions of thousands of years ago. The ancient and sacred cotton cord of the Hindu holy man who lived long-forgotten years before the Christian era and the coronation robes of this year's proud monarch, after all, have much in common. The men who go down to the sea in ships with their nets and lines can vision a textile thread stretching back through the years to join them to their brother fishermen of the prehistoric Swiss lakes.

Only after the passage of thousands of years has man acquired the temerity to attempt to duplicate what nature has lavishly bestowed for uncounted generations through the instrumentality of the sheep, the plant and the worm. Even the best modern chemist shares humbly with the physiologist the knowledge of his inability to solve the riddle of why the sheep grows wool and not feathers. For feathers and wool are strikingly alike in the kind and arrangement of the atoms which compose them. Dr. Bush[1] has said:

> I have always envied the duck. He can dive under water and come up dry. Yet his coat is pervious to air as it should be for his good health, and it fits beautifully. . . . It is cer-

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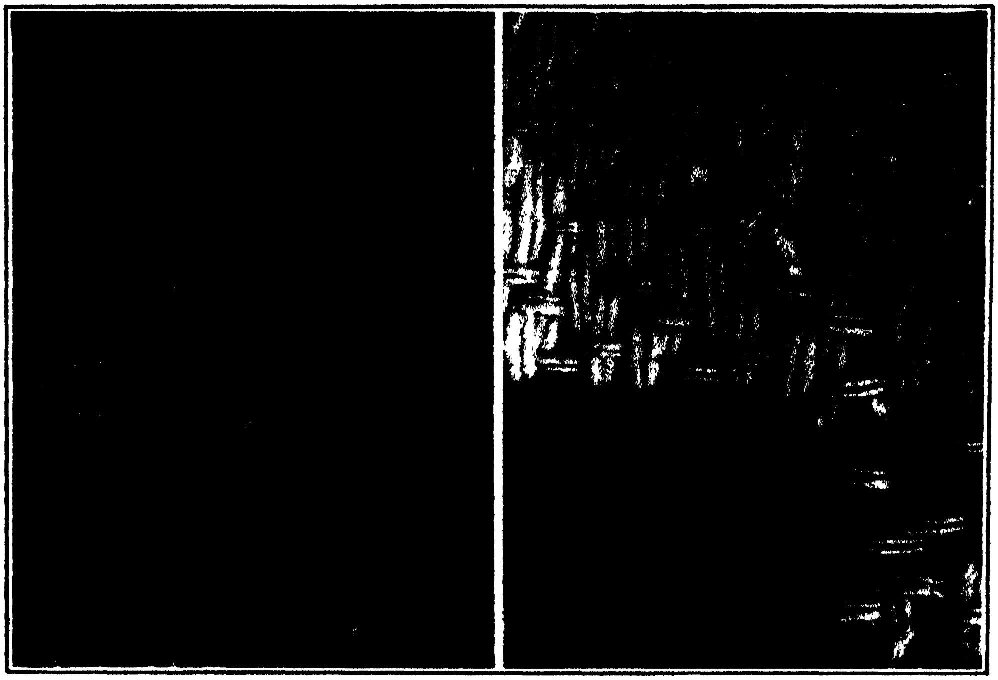
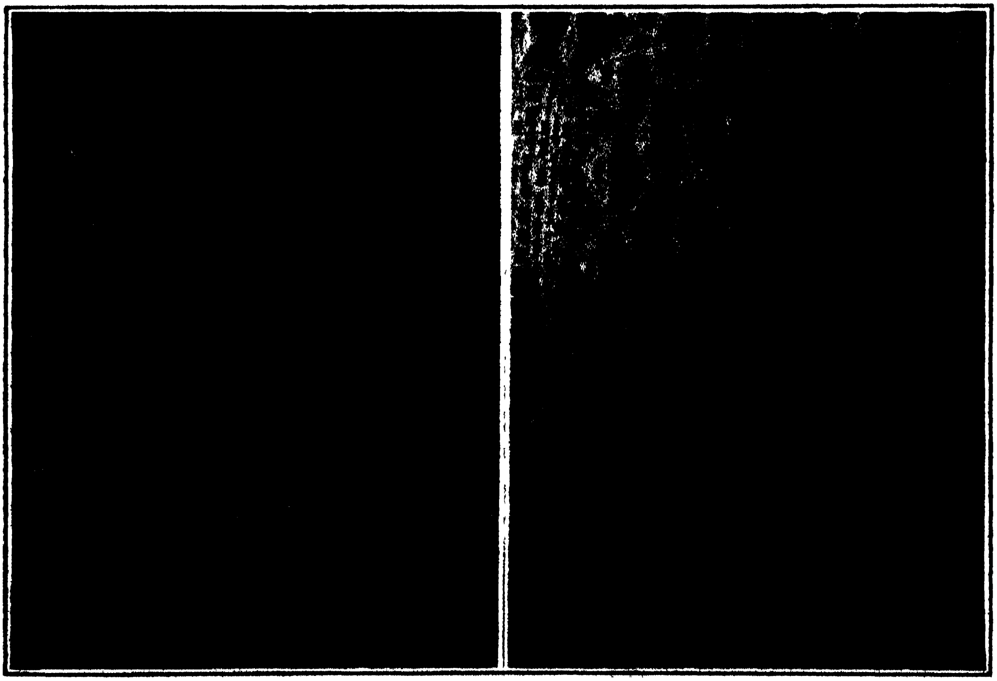
[1] Introduction to "Textile Research—A Survey of Progress," compiled by the U. S. Institute for Textile Research, Inc., M. I. T. Press, 1932.



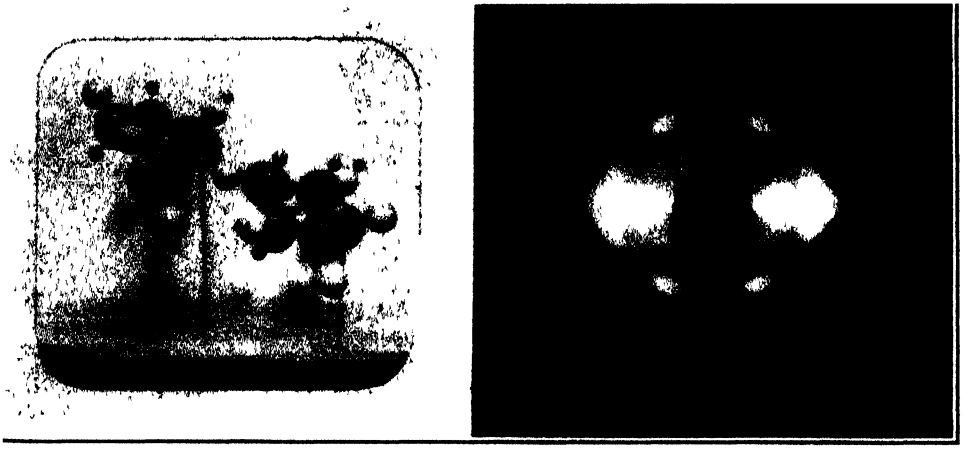
—Crawford Collection and M. I. T.

LEFT, ANCIENT PERUVIAN DOUBLE FABRIC; *RIGHT*, MODERN DOUBLE FABRIC



—Crawford Collection and M. I. T.

LEFT, ANCIENT PERUVIAN LENO WEAVE; *RIGHT*, MODERN LENO WEAVE tainly true that Solomon in all his glory was not arrayed like one of our modern women—not a queen but a woman of the people. We have progressed. Yet the lily can still exhibit more pleasing finish and coloring, to my way of thinking; and the grass of the fields presents me with more alluring gradations of greens and browns than I find in neckties. Moreover, the grass takes on more and more attractive hues after long exposure to the sun and rain, and neckties do not. This is not intended to be a criticism of the textile research worker, who, after all, has been studying his subject for only a short time, and who has produced some marvelous fibers and fabrics. Rather we should note that there is no field of human endeavor in which so much ingenuity and resourcefulness has been shown as in textiles, or which has brought more benefit to mankind.



THE MOLECULAR STRUCTURE OF FIBERS

Left, MODEL OF ONE UNIT OF CELLULOSE MOLECULE; *Right,* X-RAY DIFFRACTION PATTERN OF BAST FIBER DEMONSTRATING MOLECULAR ORIENTATION.

Rayon is an example of this resourcefulness, and it is with us to stay. Great though the story of its progress has been, its future is even greater. No one can tell what discovery of modern science will be interpreted to make rayon the most unique fiber that man has at his disposal. Nor are the natural fibers to be neglected when it comes to scientific research. The quality of most of the commonly used fibers is steadily being improved. Measurement is taking the place of guesswork. Little recognized or appreciated fiber properties are now being used to make better fabrics possible.

For many years it has been known that all textile fibers polarize the light which passes through them. This fact was of purely academic interest until the technique of x-ray diffraction photography and the discovery of what the organic chemist calls the "long chain molecule" came into prominence. Then it was realized that the architecture of the fiber (the manner in which its atomic building blocks are put together) was responsible for the double refractive properties of the fibers. And just as perfection of workmanship makes for strength and permanence in a machine or a building, so perfection of orientation of long-chain molecules makes for strength and uniformity of fiber or filament. The fiber technologist with his polarizing microscope joins the chemist with his polymerizations or degradations and the physicist with his x-ray tubes and high voltage atom splitters to aid the textile manufacturer to better utilize the products of nature's fiber producers, and those which he himself squeezes through a spinnaret.

The machines which attempt to duplicate the combining of fibers into yarn by the skilful fingers of the hand spinner whose art has passed down to him through generations from his cave-man ancestors have been with us for years. Here, too, modern science is making a critical survey of the correctness of the long-used principle of drafting. The cotton lap entering the carding machine as a sheet of matted fiber some 42 inches wide by less than one-half inch thick is drawn out in length more than 30,000,000 times to form a yarn. The problem of insuring that each successive cross section of such a yarn will contain the same number of fibers as every other is almost insoluble by such means. Science must lead the way to better yarn structure.

The familiar loom for weaving fabric uses the fundamental motions of carrying successive filling yarns through sheds formed by the separation of the warp ends, even as the earliest of American weavers, thousands of years ago, carried out the process on his bar loom. The modern loom is a marvelous combination of automatic mechanisms. All these have been added to those first built into a power loom by Cartwright (1743–1823) before he had ever seen even a hand loom. Again science must simplify and improve the fabrication of yarn into fabric.

The ancients used their madder, indigo and Tyrian purple to produce colored fabrics which would not fade. A major problem still facing the textile industry is to produce synthetic dyes which will be fast to use, washing and light. Why certain atoms (carbon, nitrogen, hydrogen and oxygen) which, in one combination, produce the indigo used to dye the silk filament, itself produced by another arrangement of the same atoms, is still to be discovered. This problem should interest all of us, for after all we are all dressed fundamentally in an impalpable powder combined with the essential element of laughing gas, a whiff of the lightest gas we know, plus a fraction of the breath of life Such are textiles. Such are some of the problems—new and old—of the textile technologist.

VERNON LYMAN KELLOGG

THE PROGRESS OF SCIENCE

VERNON LYMAN KELLOGG

VERNON LYMAN KELLOGG—scientist, author, teacher, citizen of the world, student of life, promoter of scientific organizations These are a few of the designations which may be applied to the man who has recently left us (Hartford, Connecticut, August 8, 1937) after a long and useful life which began in the home town of his famous friend, Will White (Emporia, Kansas, December 1, 1867). Between these dates the small-town Kansas boy saw much of the world, served with great leaders in many fields of human activity, contributed usefully to the advancement of biological knowledge, but, above all, stood out as an interpreter of life and its evolutionary development He received an early impulse toward biological study through association with his teacher and friend, Francis H Snow, who occupied the "settee" of science and mathematics in the early days of the University of Kansas When Snow became chancellor of the university, Kellogg served as his assistant and private secretary until he went to California in 1894. At Leland Stanford he became likewise intimately associated with its president, an even more famous biologist, David Starr Jordan, and with him for almost two decades collaborated in the production of numerous texts upon elementary biology and upon the philosophy of biology During the World War he was on leave and closely associated with another noted friend, Herbert Hoover, in the alleviation of suffering in Belgium and Poland Upon his return to this country he joined in the movement to establish the National Research Council as the executive body of the National Academy of Sciences for bringing scientific aid to the government in its war activities. Under the peace-time continuation of the National Research Council he was made its permanent secretary, in which office he continued until his tragic illness obliged him to relinquish it in 1932 In this association he was led into many related phases of scientific and philanthropic organization. There he held administrative positions in Science Service, the Council of the American Association for the Advancement of Science, the Rockefeller Foundation, the Brookings Institution and many others In most of his activities he was associated with powerful leaders whom he served as a faithful and efficient friend

In his work as an interpreter, however, he went alone, and it is here that he was most at home Even as a student he felt the urge to share his thoughts and impressions of nature with others. In the local paper he ran a column entitled "Bird Notes," in which the captivating style which characterized his writings early made itself manifest. The broad implications of biology always appealed to him and he wrote extensively upon evolution and Darwinism. In his own studies, concerned mainly with insects, he came to see the value of the practical applications of biology to human welfare and not only wrote upon this subject at some length, but proceeded to an evaluation of Luther Burbank's work. It was not surprising with this background that he turned easily to the practical use of science in the amelioration of human suffering during the war. Equally naturally he extended his thought to the problems of human behavior, so many phases of which appeared in exaggerated form under the stress of conflict, and not only was he a good interpreter of the way people think and act, but he was both able and interesting in his presentation of observations and conclusions. Kellogg's activities, though varied, sprang largely from his early manifested interest in teaching. At first this followed the conventional personal instruction of student by teacher, but very soon it extended itself into the writing of textbooks for similar types of instruction, passing then into the production of works dealing with theoretical biological questions Always, however, with the mind of the interpreter, he sought to bring to the general reader some knowledge of the way in which the problems of life and living appear to men who give them serious thought against a comparative biological background. In many other ways he showed his interest in educational matters, utilizing often toward this end the connections established in the National Research Council. Conspicuous in this direction was his chairmanship of the Division of Educational Relations, wherein he had many opportunities for the study and promotion of educational projects. As the years passed there was less and less of writing and teaching and more and more of administration, until it became all-absorbing and excessive—and then the final incapacitating illness brought a lingering end to all physical efforts, although a sustained interest in old pursuits and friends continued to the last Many responsibilities came to Kellogg and all these he met with ease and ability. Honors came also in corresponding measure, and they were carried modestly and without ostentation

C. E. McC.

THE ROCHESTER MEETING OF THE AMERICAN CHEMICAL SOCIETY

With 3,483 chemists registered, the ninety-fourth meeting of the American Chemical Society in Rochester, N. Y., from September 6 to 10, was the second largest in the history of the society, approaching the record figure of the Chemical Industry Tercentenary meeting in New York in the spring of 1935.

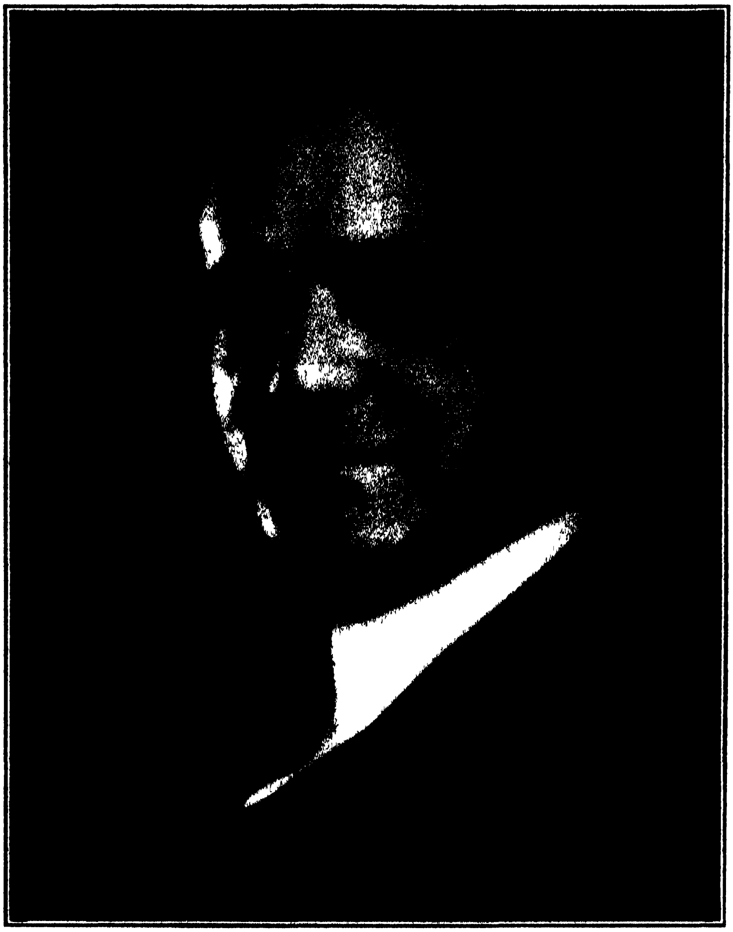
At seventeen divisions and the microchemical section, 472 scientific papers were read. The general session on Wednesday, September 8, which was Central Day, was addressed by Dr. Nevil Vincent Sidgwick, of Lincoln College, Oxford, one of the leaders of the modern school of organic chemistry in Great Britain. Dr. Sidgwick spoke on "The Uniqueness of Carbon." Dr C. E. K. Mees, director of research of the Eastman Kodak Company, illustrated "Recent Developments in Color Photography."

Dr. Edward R. Weidlein, director of the Mellon Institute of Industrial Research, gave the annual presidential address on Tuesday evening at the Eastman Theater, depicting "A World of Change." America, Dr. Weidlein declared, has achieved the chemical leadership of the world.

"It grows more and more apparent that to help one's country to be chemically independent is the profoundest kind of patriotism," Dr. Weidlein concluded "The objective of scientific research to-day, moreover, is broader than the solution of technological and chemical problems. It takes into its view the responsibility for enlivening the imagination of the masses who will be the chief beneficiaries of these new ways of living. A true scientist . . . expects to live in a changing world."

Rochester's three largest hotels, the Seneca, Sagamore and Powers, were overrun during the meeting. While the Seneca was the headquarters hotel, divisional meetings were also held at the Eastman School of Music, the Sagamore, the Rochester Club, the Powers, the Rochester Gas and Electric Corporation Building and the Columbus Building.

The society's council, convening on Wednesday morning, gave a rising vote of thanks to the members of the Rochester

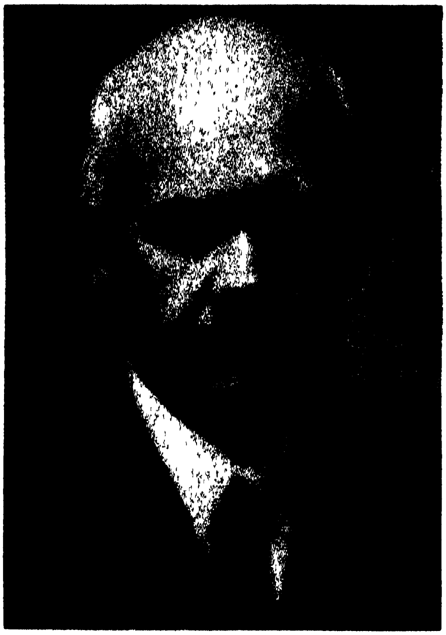


DEAN FRANK CLIFFORD WHITMORE
PENNSYLVANIA STATE COLLEGE, PRESIDENT OF THE AMERICAN CHEMICAL SOCIETY.

section "for such a good meeting." Secretary Charles L. Parsons reported:

> 1937 has been a banner year for the American Chemical Society. To date, 2,773 new members have joined the society, making a total membership of 20,538. Subscriptions to the society's journals have also notably increased. When it is taken into consideration that the budgeted expenditure for the society in 1937 is in excess of $622,000, a rough idea is gained of the extent of the society's business and the return it makes to its membership. This is especially emphasized by the fact that of this amount only $186,700 comes from membership dues. Funds necessary for the Third Decennial Index were raised, chemical industry contributing over $100,000 of this amount. Three new local sections have been chartered, one at Wilson Dam, one in the Texas Panhandle and one at Dallas and Fort Worth. Most important of all, federal incorporation to take place January 1, 1938, has been granted by Congress and the act has been signed by the President. This is an accomplishment of the utmost value to the success of the American Chemical Society and its opportunities for usefulness.

The council announced the award of the first Francis P. Garvan gold medal to Dr. Emma P. Carr, of Mt. Holyoke College, "for her researches in physical chemistry, especially on the structure of organic molecules by means of absorption studies in the far ultra-violet portion of the spectrum." Dr. Carr, who



DR. NEVIL VINCENT SIDGWICK
LINCOLN COLLEGE, OXFORD UNIVERSITY, ENGLAND, WHO ADDRESSED A GENERAL SESSION OF THE AMERICAN CHEMICAL SOCIETY.

DR. C. E. K MEES
DIRECTOR OF RESEARCH AND DEVELOPMENT, EASTMAN KODAK COMPANY, ROCHESTER, N. Y., WHO SPOKE BEFORE A GENERAL MEETING.

DR. EMMA PERRY CARR
MOUNT HOLYOKE COLLEGE.

DR. E. BRIGHT WILSON, JR.
HARVARD UNIVERSITY.

is on sabbatical leave, will receive the medal at the ninety-fifth meeting in Dallas, Texas.

The establishment of a prize of $1,000 and a gold medal for outstanding achievement in milk chemistry by the Borden Company was also announced. The award will be made annually for three years beginning in 1939 under the direction of the society.

The Langmuir Prize of $1,000 was presented on Wednesday afternoon to Dr. E Bright Wilson, assistant professor of chemistry in Harvard University, twenty-eight years of age, for outstanding experimental work in physical chemistry

Seventy-one foreign chemists attended the meeting, which "wrecked" the housing facilities of Rochester. Every hotel room in the city was taken, as well as the University of Rochester dormitories and many rooms in private homes Of the foreign chemists, forty-nine were from Canada, three from Germany, eight from England, two from New Zealand, three from Holland, two from Belgium and one each from Brazil, Puerto Rico, British West Indies and Dutch West Indies.

The plant trips arranged for Rochester were an exceptionally successful feature of the meeting. All Rochester industries were extremely hospitable, opening doors to visiting chemists without exception. There was splendid entertainment and about forty-five special luncheons, dinners and group meetings.

The Symposium on "Are Patents on Medicinal Discoveries and on Foods in the Public Interest?" attracted the largest attendance (something over 500) and the speakers—Dr. Morris Fishbein, of the American Medical Association, Dean H. L Russell, of the Wisconsin Alumni Research Foundation, and George B. Schley, Indianapolis attorney—were followed by lively and extensive discussion from the floor.

The two-day Symposium on Gaseous Combustion, convening through Thursday and Friday, was the longest one of the meeting and was also very well attended, with time allowance for discussion found too short Growing interest in the programs of the Microchemistry Section caused its room to be overflowing at all times.

In the History of Chemistry Division, a dramatization of Jane Marcet's "Conversations of Chemistry" was a departure from the standard example of scientific paper. Four evening radio broadcasts brought chemical science down to chatty, informal language, under the direction of D. H. Killeffer, of New York Nearly a dozen show windows in Rochester department stores and in the Gas and Electric Building were devoted to special chemical exhibits.

CORRESPONDENT

THE SEPARATION OF NITROGEN AND POTASSIUM ISOTOPES

SEPARATION of the heavy isotope of nitrogen for the first time in quantities sufficient to provide a new "tagged" atom for far-reaching investigations of physiological processes and other scientific enigma was announced to the American Chemical Society, meeting at Rochester, by Professor Harold C. Urey, of Columbia University, winner of the 1934 Nobel prize in chemistry for his discovery of "heavy water."

Dr. Urey and his co-workers, Dr. John R. Huffman, H. G. Thode and Marvin Fox, have developed after two years' effort a distinctly chemical method by which two tenths of a gram of "heavy" nitrogen can be produced every twenty-four hours, a speed one hundred times greater than previously attained by scientists who had separated the isotopes, or chemical "twins," by physical means based on diffusion of gases.

With a concentration of heavy nitrogen provided by Dr. Urey, Dr. Rudolf Schoenheimer, assistant professor of biological chemistry in the Columbia Uni-

DR. HAROLD CLAYTON UREY, NOBEL PRIZE WINNER (LEFT) AND DR. JOHN R. HUFFMAN

WATCH THE 35-FOOT COLUMN IN THE CHEMISTRY LABORATORIES OF COLUMBIA UNIVERSITY BY WHICH THE HEAVY ISOTOPE OF NITROGEN, OCCURRING IN THE RATIO OF 1 TO EVERY 262 ORDINARY NITROGEN ATOMS, WAS SEPARATED IN SIZABLE QUANTITIES FOR THE FIRST TIME. DR. UREY AND HIS CO-WORKERS REPORTED TO THE AMERICAN CHEMICAL SOCIETY, MEETING IN ROCHESTER, N. Y., THAT TWO TENTHS OF A GRAM OF "HEAVY" NITROGEN CAN BE PRODUCED EVERY 24 HOURS, A SPEED 100 TIMES GREATER THAN PREVIOUSLY ATTAINED. THE COLUMN, A COUNTERCURRENT "SCRUBBING" APPARATUS OF THE DISTILLATION TYPE, CONTAINS 1,200 STEEL CONES FITTED INTO A SIX-INCH PIPE TOGETHER WITH ALTERNATE CONES ATTACHED TO A ROTATING ROD IN THE CENTER, PROVIDING A LARGE SURFACE FOR REACTION BETWEEN AN AMMONIUM SULFATE SOLUTION AND AMMONIA GAS.

versity School of Medicine, was able to establish that hippuric acid, or benzoylglycine, present in foodstuffs, is directly absorbed through the intestinal wall, thereby solving one question concerning the body's chemical disposal of a waste product. Dr. Schoenheimer, together with David Rittenberg, Albert S. Keston, Sarah Ratner and Mr. Fox, reported this first research employing heavy nitrogen as a "tagged" atom in a paper read on September 7 before the Division of Biological Chemistry of the society.

The first partial separation of the isotopes of potassium, another element vital to life, and a factor in regulating heart beat, is also announced by Dr. Urey, T. Ivan Taylor, of Columbia University, and Dr A. Keith Brewer, of the U. S. Bureau of Chemistry and Soils. A 5 per cent increase in the normal concentration of potassium of atomic weight 41 has been obtained in the Columbia laboratories by chemical means, a shift in the potassium isotope abundance hitherto found impossible. The method was originated by Dr Urey and Mr. Taylor for their work on potassium and lithium isotopes.

Analyses show that the occurrence of the three potassium isotopes of atomic weights 39, 40 and 41, vary in minerals, seaweed and the marrow of bones. In bone marrow, where red blood cells are produced, the relative amount of isotope 41 is greater. The very rare isotope 40 is known to be radioactive. Isotope 39 is the abundant one.

"If 41 is increased in concentration in life, it is reasonable to conclude that 40 would be also," Dr. Brewer pointed out. "Isotope 40 is radioactive. Therefore interesting speculations arise as to where experimentation in the separation of these isotopes, so important to the biochemistry of plants and animals, may lead."

The total amount of heavy nitrogen in concentration obtained at Columbia was as follows: 20 grams containing 2.5 per cent. of the heavy isotope; 33 grams of 2.34 per cent. concentration, 400 grams of lower concentrations.

The heavy isotope of nitrogen, which has an atomic weight of 15, is normally present to the extent of .38 per cent. in all nitrogen, that is, one nitrogen atom in every 263 is of the heavy variety. It was discovered by S. M Naude, of the University of Chicago, in 1929. Ordinary nitrogen has an atomic weight of 14. A rather rare element, nitrogen is an important constituent of protoplasm and of all proteins It is utilized by plants and animals in nutrition, following a continuous cycle through nature The waste matter of animals is high in nitrogen content About four fifths of the atmosphere is composed of nitrogen, and it also is found in ammonia, explosives, dyes and fertilizers

To concentrate the heavy nitrogen, Dr Urey and his coworkers used a countercurrent "scrubbing" apparatus of the distillation column type, originally designed by Dean George B Pegram, of the Columbia Graduate Faculties, and recently employed in the successful mass production of the heavy isotope of oxygen. It is thirty-five feet long and contains 1,200 steel cones fitted into a six-inch pipe Alternate cones are attached to a rotating rod in the center of the column, thus providing a large surface for reaction.

A slight-variation in the physical and chemical properties of the nitrogen isotopes makes possible the process, which depends upon a difference in distribution of nitrogen isotopes between a liquid solution and a gas. In other words, the atomic weight of nitrogen in ammonia gas which is in equilibrium with a solution of ammonium sulfate differs from that of nitrogen in the ammonium sulfate by about five parts per million.

A solution of ammonium sulfate, which is an important constituent of fertilizers, is allowed to run down through the center of the column while ammonia gas rises from the bottom of the column The ammonia gas dissolves in the solution; the ammonia molecules, each containing one atom of nitrogen and three atoms of hydrogen, leave the gas and go into the solution, changing places with the ammonia molecules in the solution

The resulting ammonium sulfate solution contains about 2 per cent. more heavy nitrogen than did the ammonia gas, because the heavier atoms tend to stay in the liquid, while the lighter escape in the gas. There is thus a net flow of heavy nitrogen to the bottom of the column. As the solution collects at the bottom of the column, the ammonia is removed from it and sent upward through the column in the form of gas, again reacting with the ammonium sulfate to create a solution still richer in heavy nitrogen.

This process of reconversion becomes continuous, reaching an efficiency by which two tenths of a gram of heavy nitrogen is produced every twenty-four hours in a concentration six and one half times that which normally exists. Only one thousandth of a gram of heavy nitrogen in twenty-four hours had been previously achieved—a quantity too minute for most research purposes.

While this chemical method was proposed by Dr. Urey in 1935 and some separation of the nitrogen and carbon isotopes was secured about a year ago, this is the first time that such a large separation on an extensive scale has been obtained Professor Gilbert N Lewis and Dr R T. MacDonald, of the University of California, have used a similar method to secure an appreciable separation of the lithium isotopes.

Correspondent

RACIAL DIFFERENCES

ANITA LEGANA WITH TROPHY

Dr Franz Boas, the leading anthropologist now living, who retired from his professorship in Columbia University last year at the age of seventy-seven years, holds that no fundamental differences among the races have been proved It is difficult to understand this point of view, for in the course of evolution there has been a development of intelligence and other traits, and it is improbable that the different races should now be on the same level. In the artificial variations of the lower animals created by us there are great differences, both in physical traits and in behavior. We have the Shetland pony, the nervous and bony race horse, the stolid and massive Percheron. The dogs vary from the lap-dogs of the ladies to the great Danes, from the clever sheep-dog to the stupid bull-dog.

But the contention of Professor Boas is supported and common sense is confounded by the apparent equality of the human races in athletic performance. Most people still remember that a Negro was the hero in the recent Olympic games. The writer of this note happened to be present when the final association football game was played in the Olympiad at Amsterdam

LEFT TO RIGHT: DONALD BUDGE, HALCOMBE WARD, BARON VON CRAMM

some ten years ago A dozen or more nations contended; the victors were from Egypt and the Argentine. England did not play, as she claimed that the players on the Argentine team were not amateurs because their wages as factory workers were continued during their trip to Amsterdam. As a matter of fact they were true amateurs, for they probably worked in the factory ten hours a day for six days a week and only played football as a sport on Sundays. The English were probably professionals, for it is likely that their principal concern was with sports and they had been trained by paid coaches.

Tennis perhaps is the best evidence for the similarity of different races in their muscular and nervous equipment. The international champions and their runners up come from many nations. At the recent games at Forest Hills, which are the occasion of this note, the finals in the men's singles were between an American and a German, in the women's between a Pole and a Chilean. The Californians, and especially their Helens, have probably done so well not through physical superiority, but owing to climatic and social conditions.

There are obvious physical differences between the sexes. As the policeman said to the woman who wanted to know why she could not bathe in the same attire as the men, "women is different." The psychologists have found it difficult to find measurable differences in mental equipment. One of our most distinguished psychologists found in experiments in the association of ideas that women thought more about dress than men; another psychologist of nearly equal standing found the opposite—the former was a man, the latter a woman. The accompanying picture does illustrate a difference that appears to be real.

Budge could not faint from excitement over winning a tennis match after two sets.

Herr Hitler knows about the playgrounds of Eton and the methods of Sparta. When long ago the writer of this note was a student in Germany, there were in the universities no athletic games except sport duels. He, however, played football several times in a Polytechnic school and could at any time run through the line to the goal, for though he weighed only a hundred and fifty pounds the players respectfully moved out of his way. Now all this is different, but not through any racial change.

Incidentally it may be remarked that even the physiognomy of the races varies less than is commonly assumed. In the photograph many will think that one man looks like a German, the other like an American. But if photographs of ten Germans and ten Americans are mixed it is difficult to sort them out, apart from their hair and clothes. Indeed under these conditions it is difficult, often impossible, to discriminate criminals from clergymen, men from women. The winning woman in the picture might have come from any Caucasian race.

The problem as to whether national differences are frequently set by inheritance or are functional and due to environmental conditions is of fundamental importance. Do "nations delight to fight because it is their nature to," or only because they have been badly brought up? May not wars disappear as quickly as duels when their futility is realized?

J. McK. C.

ANITA LEGANA BEING CARRIED OFF THE COURT AT FOREST HILLS, LONG ISLAND

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THE PROGRESS OF PHYSICS[1]

By the late LORD RAYLEIGH

PROFESSOR OF EXPERIMENTAL PHYSICS IN THE UNIVERSITY OF CAMBRIDGE

It is no ordinary meeting of the British Association which I have now the honor of addressing. For more than fifty years the Association has held its autumn gathering in various towns of the United Kingdom, and within those limits there is, I suppose, no place of importance which we have not visited. And now, not satisfied with past successes, we are seeking new worlds to conquer. When it was first proposed to visit Canada, there were some who viewed the project with hesitation. For my own part, I never quite understood the grounds of their apprehension. Perhaps they feared the thin end of the wedge. When once the principle was admitted, there was no knowing to what it might lead. So rapid is the development of the British Empire, that the time might come when a visit to such out-of-the-way places as London or Manchester could no longer be claimed as a right, but only asked for as a concession to the susceptibilities of the English. But seriously, whatever objections may have at first been felt soon were outweighed by the consideration of the magnificent opportunities which your hospitality affords of extending the sphere of our influence and of becoming acquainted with a part of the Queen's dominion which, associated with splendid memories of the past, is advancing daily by leaps and bounds to a position of importance such as not long ago was scarcely dreamed of. For myself, I am not a stranger to your shores. I remember well the impression made upon me, seventeen years ago, by the wild rapids of the St. Lawrence, and the gloomy grandeur of the Saguenay. If anything impressed me more, it was the kindness with which I was received by yourselves, and which I doubt not will be again extended not merely to myself but to all the English members of the Association. I am confident that those who have made up their minds to cross the ocean will not repent their decision, and that, apart altogether from scientific interests, great advantage may be expected from this visit. We Englishmen ought to know more than we do of matters relating to the Colonies, and anything which tends to bring the various parts of the Empire into closer contact can hardly be over-valued. It is pleasant to think that this Association is the means of furthering an object which should be dear to the hearts of all of us; and I venture to say that a large proportion of the visitors to this country will be astonished by what they see, and will carry home an impression which time will not readily efface.

To be connected with this meeting is to me a great honor, but also a great responsibility. In one respect, especially, I feel that the Association might have done well to choose another President. My own tastes have led me to study mathematics and physics rather than geology and biology, to which naturally more attention turns in a new country, presenting as it does a fresh field for investigation. A chronicle of achievements in these departments by workers from among yourselves would have been suitable to the occasion, but could not come from me. If you would have preferred a different subject for this address, I hope at least that you will not hold me entirely responsible.

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[1] Presidential address before the meeting of the British Association for the Advancement of Science, Montreal, 1884.

At annual gatherings like ours the pleasure with which friends meet friends again is sadly marred by the absence of those who can never more take their part in our proceedings. Last year my predecessor in this office had to lament the untimely loss of Spottiswoode and Henry Smith, dear friends of many of us, and prominent members of our Association. And now, again, a well-known form is missing. For many years Sir W. Siemens has been a regular attendant at our meetings, and to few indeed have they been more indebted for success. Whatever the occasion, in his Presidential Address of two years ago, or in communications to the Physical and Mechanical Sections, he had always new and interesting ideas, put forward in language which a child could understand, so great a master was he of the art of lucid statement in his adopted tongue. Practice with Science was his motto. Deeply engaged in industry, and conversant all his life with engineering operations, his opinion was never that of a mere theorist. On the other hand, he abhorred rule of thumb, striving always to master the scientific principles which underlie rational design and invention.

It is not necessary that I should review in detail the work of Siemens. The part which he took, during recent years, in the development of the dynamo machine must be known to many of you. We owe to him the practical adoption of the method, first suggested by Wheatstone, of throwing into a shunt the coils of the field-magnets, by which a greatly improved steadiness of action is obtained. The same characteristics are observable throughout—a definite object in view and a well-directed perseverance in overcoming the difficulties by which the path is usually obstructed.

These are indeed the conditions of successful invention. The world knows little of such things, and regards the new machine or the new method as the immediate outcome of a happy idea. Probably, if the truth were known, we should see that, in nine cases out of ten, success depends as much upon good judgment and perseverance as upon fertility of imagination. The labors of our great inventors are not unappreciated, but I doubt whether we adequately realize the enormous obligations under which we lie. It is no exaggeration to say that the life of such a man as Siemens is spent in the public service; the advantages which he reaps for himself being as nothing in comparison with those which he confers upon the community at large.

As an example of this it will be sufficient to mention one of the most valuable achievements of his active life—his introduction, in conjunction with his brother, of the regenerative gas furnace, by which an immense economy of fuel (estimated at millions of tons annually) has been effected in the manufacture of steel and glass. The nature of this economy is easily explained. Whatever may be the work to be done by the burning of fuel, a certain *temperature* is necessary. For example, no amount of heat in the form of boiling water would be of any avail for the fusion of steel. When the products of combustion are cooled down to the point in question, the heat which they still contain is useless as regards the purpose in view. The importance of this consideration depends entirely upon the working temperature. If the object be the evaporation of water or the warming of a house, almost all the heat may be extracted from the fuel without special arrangements. But it is otherwise when the temperature required is not much below that of combustion itself, for then the escaping gases carry away with them the larger part of the whole heat developed. It was to meet this difficulty that the regenerative furnace was devised. The products of combustion, before dismissal into the chimney, are caused to pass through piles of loosely stacked fire-brick, to which they give up their heat. After a time the fire-brick, upon which the gases first impinge, becomes nearly as hot as the furnace itself. By suitable valves the burnt gases are then diverted through another stack of brickwork, which they heat up in like manner, while the heat stored up in the first stack is utilized to warm the unburnt gas and air on their way to the furnace. In this way almost all the heat developed at a high temperature during the combustion is made available for the work in hand.

As it is now several years since your presidential chair has been occupied by a professed physicist, it may naturally be expected that I should attempt some record of recent progress in that branch of science, if indeed such a term be applicable. For it is one of the difficulties of the task that subjects as distinct as mechanics, electricity, heat, optics, and acoustics, to say nothing of astronomy and meteorology, are included under physics. Any one of these may well occupy the life-long attention of a man of science, and to be thoroughly conversant with all of them is more than can be expected of any one individual, and is probably incompatible with the devotion of much time and energy to the actual advancement of knowledge. Not that I would complain of the association sanctioned by common parlance. A sound knowledge of at least the principles of general physics is necessary to the cultivation of any department. The predominance of the sense of sight as the medium of communication with the outer world, brings with it dependence upon the science of optics; and there is hardly a branch of science in which the effects of *temperature* have not (often without much success) to be reckoned with. Besides the neglected borderland between two branches of knowledge is often that which best repays cultivation, or, to use a metaphor of Maxwell's, the greatest benefits may be derived from a cross-fertilization of the sciences. The wealth of material is an evil only from the point of view of one of whom too much may be expected. Another difficulty incident to the task, which must be faced, but can not be overcome, is that of estimating rightly the value, and even the correctness, of recent work. It is not always that which seems at first the most important that proves in the end to be so. The history of science teems with examples of discoveries which attracted little notice at the time, but afterwards have taken root downwards and borne much fruit upwards.

One of the most striking advances of recent years is in the production and application of electricity upon a large scale—a subject to which I have already had occasion to allude in connection with the work of Sir W. Siemens. The dynamo machine is indeed founded upon discoveries of Faraday now more than half a century old; but it has required the protracted labors of many inventors to bring it to its present high degree of efficiency. Looking back at the matter, it seems strange that progress should have been so slow. I do not refer to details of design, the elaboration of which must always, I suppose, require the experience of actual work to indicate what parts are structurally weaker than they should be, or are exposed to undue wear and tear. But with regard to the main features of the problem it would almost seem as if the difficulty lay in want of faith. Long ago it was recognized that electricity derived from chemical action is (on a large scale) too expensive a source of mechanical power, notwithstanding the fact that (as proved by Joule in 1846) the conversion of electrical into mechanical work can be effected with great economy. From this it is an evident consequence that electricity may advantageously be obtained from mechanical power; and one can not help thinking that if the fact had been borne steadily in mind, the development of the dynamo might have been much more rapid. But discoveries and inventions are apt to appear obvious when regarded from the standpoint of accomplished fact; and I draw attention to the matter only to point the moral that we do well to push the attack persistently when we can be sure beforehand that the obstacles to be overcome are only difficulties of contrivance, and that we are not vainly fighting unawares against a law of Nature.

The present development of electricity on a large scale depends, however, almost as much upon the incandescent lamp as upon the dynamo. The success of these lamps demands a very perfect vacuum—not more than about one millionth of the normal quantity of air should remain—and it is interesting to recall that, twenty years ago, such vacua were rare even in the laboratory of the physicist. It is pretty safe to say that these wonderful results would never have been accomplished had practical applications alone been in view. The way was prepared by an army of scientific men whose main object was the advancement of knowledge, and who could scarcely have imagined that the processes which they elaborated would soon be in use on a commercial scale and intrusted to the hands of ordinary workmen.

When I speak in hopeful language of practical electricity, I do not forget the disappointment within the last year or two of many over-sanguine expectations. The enthusiasm of the inventor and promoter are necessary to progress, and it seems to be almost a law of nature that it should overpass the bounds marked out by reason and experience. What is most to be regretted is the advantage taken by speculators of the often uninstructed interest felt by the public in novel schemes by which its imagination is fired. But looking forward to the future of electric lighting, we have good ground for encouragement. Already the lighting of large passenger-ships is an assured success, and one which will be highly appreciated by those travelers who have experienced the tedium of long winter evenings unrelieved by adequate illumination. Here, no doubt, the conditions are in many respects especially favorable. As regards space, life on board ship is highly concentrated; while unity of management and the presence on the spot of skilled engineers obviate some of the difficulties that are met with under other circumstances. At present we have no experience of a house-to-house system of illumination on a great scale and in competition with cheap gas; but preparations are already far advanced for trial on an adequate scale in London. In large institutions, such as theaters and factories, we all know that electricity is in successful and daily extending operation.

When the necessary power can be obtained from the fall of water, instead of from the combustion of coal, the conditions of the problem are far more favorable. Possibly the severity of your winters may prove an obstacle, but it is impossible to regard your splendid river without the thought arising that the day may come when the vast powers now running to waste shall be bent into your service. Such a project demands of course the most careful consideration, but it is one worthy of an intelligent and enterprising community.

The requirements of practice react in the most healthy manner upon scientific electricity. Just as in former days the science received a stimulus from the application to telegraphy, under which everything relating to measurement on a small scale acquired an importance and development for which we might otherwise have had long to wait, so now the requirements of electric lighting are giving rise to a new development of the art of measurement upon a large scale, which can not fail to prove of scientific as well as practical importance. Mere change of scale may not at first appear a very important matter, but it is surprising how much modification it entails in the instruments, and in the processes of measurement. For instance, the resistance coils on which the electrician relies in dealing with currents whose maximum is a fraction of an ampere fail altogether when it becomes a question of hundreds, not to say thousands, of amperes.

The powerful currents, which are now at command, constitute almost a new weapon in the hands of the physicist. Effects which in old days were rare and difficult of observation may now be produced at will on the most conspicuous scale. Consider for a moment Faraday's great discovery of the "Magnetization of Light," which Tyndall likens to the Weisshorn among mountains, as high, beautiful, and alone. This judgment (in which I fully concur) relates to the scientific aspect of the discovery, for to the eye of sense nothing could have been more insignificant. It is even possible that it might have eluded altogether the penetration of Faraday, had he not been provided with a special quality of very heavy glass. At the present day these effects may be produced upon a scale that would have delighted their discoverer, a rotation of the plane of polarization through 180° being perfectly feasible. With the aid of modern appliances, Kundt and Röntgen in Germany, and H. Becquerel in France, have detected the rotation in gases and vapors, where, on account of its extreme smallness, it had previously escaped notice.

Again, the question of the magnetic saturation of iron has now an importance entirely beyond what it possessed at the time of Joule's early observations. Then it required special arrangements purposely contrived to bring it into prominence. Now in every dynamo machine, the iron of the field-magnets approaches a state of saturation, and the very elements of an explanation of the action require us to take the fact into account. It is indeed probable that a better knowledge of this subject might lead to improvements in the design of these machines.

Notwithstanding the important work of Rowland and Stoletow, the whole theory of the behavior of soft iron under varying magnetic conditions is still somewhat obscure. Much may be hoped from the induction balance of Hughes, by which the marvelous powers of the telephone are applied to the discrimination of the properties of metals, as regards magnetism and electric conductivity.

The introduction of powerful alternate-current in machines by Siemens, Gordon, Ferranti, and others, is likely also to have a salutary effect in educating those so-called practical electricians whose ideas do not easily rise above ohms and volts. It has long been known that when the changes are sufficiently rapid, the phenomena are governed much more by induction, or electric inertia, than by mere resistance. On this principle much may be explained that would otherwise seem paradoxical. To take a comparatively simple case, conceive an electromagnet wound with two contiguous wires, upon which acts a given rapidly periodic electromotive force. If one wire only be used, a certain amount of heat is developed in the circuit. Suppose now that the second wire is brought into operation in parallel—a proceeding equivalent to doubling the section of the original wire. An electrician accustomed only to constant currents would be sure to think that the heating effect would be doubled by the change, as much heat being developed in each wire separately as was at first in the single wire. But such a conclusion would be entirely erroneous. The total current, being governed practically by the self-induction of the circuit, would not be augmented by the accession of the second wire, and the total heating effect, so far from being doubled, would, in virtue of the superior conductivity, be halved.

During the last few years much interest has been felt in the reduction to an absolute standard of measurements of electromotive force, current, resistance, &c., and to this end many laborious investigations have been undertaken. The subject is one that has engaged a good deal of my own attention, and I should naturally have felt inclined to dilate upon it, but that I feel it to be too abstruse and special to be dealt with in detail upon an occasion like the present. As regards resistance, I will merely remind you that the recent determinations have shown a so greatly improved agreement that the Conference of Electricians assembled at Paris in May have felt themselves justified in defining the ohm for practical use as the resistance of a column of mercury of 0° C., one square millimeter in section, and 106 cm in length—a definition differing by a little more than 1 per cent. from that arrived at twenty years ago by a committee of this Association.

A standard of resistance once determined upon can be embodied in a "resistance coil," and copied without much trouble, and with great accuracy. But in order to complete the electrical system, a second standard of some kind is necessary, and this is not so easily embodied in a permanent form. It might conveniently consist of a standard galvanic cell, capable of being prepared in a definite manner, whose electromotive force is once for all determined. Unfortunately, most of the batteries in ordinary use are for one reason or another unsuitable for this purpose, but the cell introduced by Mr. Latimer Clark, in which the metals are zinc in contact with saturated zinc sulphate and pure mercury in contact with mercurous sulphate, appears to give satisfactory results. According to my measurements, the electromotive force of this cell is 1.435 theoretical volts.

We may also conveniently express the second absolute electrical measurement necessary to the completion of the system by taking advantage of Faraday's law that the quantity of metal decomposed in an electrolytic cell is proportional to the whole quantity of electricity that passes. The best metal for the purpose is silver, deposited from a solution of the nitrate or of the chlorate. The results recently obtained by Prof. Kohlrausch and by myself are in very good agreement, and the conclusion that one ampere flowing for one hour decomposes 4.025 grains of silver, can hardly be in error by more than a thousandth part. This number being known, the silver voltameter gives a ready and very accurate method of measuring currents of intensity varying from one tenth of an ampere to four or five amperes.

The beautiful and mysterious phenomena attending the discharge of electricity in nearly vacuous spaces have been investigated and in some degree explained by De La Rue, Crookes, Schuster, Moulton, and the lamented Spottiswoode, as well as by various able foreign experimenters. In a recent research Crookes has sought the origin of a bright citron-colored band in the phosphorescent spectrum of certain earths, and after encountering difficulties and anomalies of a most bewildering kind, has succeeded in proving that it is due to yttrium, an element much more widely distributed than had been supposed. A conclusion like this is stated in a few words, but those only who have undergone similar experience are likely to appreciate the skill and perseverance of which it is the final reward.

A remarkable observation by Hall of Baltimore, from which it appeared that the flow of electricity in a conducting sheet was disturbed by magnetic force, has been the subject of much discussion. Mr. Shelford Bidwell has brought forward experiments tending to prove that the effect is of a secondary character, due in the first instance to the mechanical force operating upon the conductor of an electric current when situated in a powerful magnetic field. Mr. Bidwell's view agrees in the main with Mr. Hall's division of the metals into two groups according to the direction of the effect.

Without doubt the most important achievement of the older generation of scientific men has been the establishment and application of the great laws of thermo-dynamics, or, as it is often called, the mechanical theory of heat. The first law, which asserts that heat and mechanical work can be transformed one into the other at a certain fixed rate, is now well understood by every student of physics, and the number expressing the mechanical equivalent of heat resulting from the experiments of Joule has been confirmed by the researches of others, and especially of Rowland. But the second law, which practically is even more important than the first, is only now beginning to receive the full appreciation due to it. One reason of this may be found in a not unnatural confusion of ideas. Words do not always lend themselves readily to the demands that are made upon them by a growing science, and I think that the almost unavoidable use of the word equivalent in the statement of the first law is partly responsible for the little attention that is given to the second. For the second law so far contradicts the usual statement of the first, as to assert that equivalents of heat and work are not of equal value. While work can always be converted into heat, heat can only be converted into work under certain limitations. For every practical purpose the work is worth the most, and when we speak of equivalents, we use the word in the same sort of special sense as that in which chemists speak of equivalents of gold and iron. The second law teaches us that the real value of heat, as a source of mechanical power, depends upon the temperature of the body in which it resides; the hotter the body in relation to its surroundings, the more available the heat.

In order to see the relations which obtain between the first and the second law of thermo-dynamics, it is only necessary for us to glance at the theory of the steam-engine. Not many years ago calculations were plentiful demonstrating the inefficiency of the steam-engine on the basis of a comparison of the work actually got out of the engine with the mechanical equivalent of the heat supplied to the boiler. Such calculations took into account only the first law of thermo-dynamics, which deals with the equivalents of heat and work, and have very little bearing upon the practical question of efficiency, which requires us to have regard also to the second law. According to that law the fraction of the total energy which can be converted into work depends upon the relative temperatures of the boiler and condenser; and it is, therefore, manifest that, as the temperature of the boiler can not be raised indefinitely, it is impossible to utilize all the energy which, according to the first law of thermo-dynamics, is resident in the coal.

On a sounder view of the matter, the efficiency of the steam-engine is found to be so high that there is no great margin remaining for improvement. The higher initial temperature possible in the gas-engine opens out much wider possibilities, and many good judges look forward to a time when the steam-engine will have to give way to its younger rival.

To return to the theoretical question, we may say with Sir W. Thomson that, though energy can not be destroyed, it ever tends to be dissipated, or to pass from more available to less available forms. No one who has grasped this principle can fail to recognize its immense importance in the system of the universe. Every change, chemical, thermal, or mechanical—which takes place, or can take place, in Nature, does so, at the cost of a certain amount of available energy. If, therefore, we wish to inquire whether or not a proposed transformation can take place, the question to be considered is whether its occurrence would involve dissipation of energy. If not, the transformation is (under the circumstances of the case) absolutely excluded. Some years ago, in a lecture at the Royal Institution, I endeavored to draw the attention of chemists to the importance of the principle of dissipation in relation to their science, pointing out the error of the usual assumption that a general criterion is to be found in respect of the development of heat. For example, the solution of a salt in water is, if I may be allowed to phrase, a downhill transformation. It involves dissipation of energy, and can therefore go forward; but in many cases it is associated with the absorption rather than with the development of heat. I am glad to take advantage of the present opportunity in order to repeat my recommendation, with an emphasis justified by actual achievement. The foundations laid by Thomson now bear an edifice of no mean proportions, thanks to the labors of several physicists, among whom must be especially mentioned Willard Gibbs and Helmholtz. The former has elaborated a theory of the equilibrium of heterogeneous substances, wide in its principles, and we can not doubt far-reaching in its consequences. In a series of masterly papers Helmholtz has developed the conception of *free energy* with very important applications to the theory of the galvanic cell. He points out that the mere tendency to solution bears in some cases no small proportion to the affinities more usually reckoned chemical, and contributes largely to the total electromotive force. Also in our own country Dr. Alder Wright has published some valuable experiments relating to the subject.

From the further study of electrolysis we may expect to gain improved views as to the nature of the chemical reactions, and of the forces concerned in bringing them about. I am not qualified—I wish I were—to speak to you on recent progress in general chemistry. Perhaps my feelings towards a first love may blind me, but I can not help thinking that the next great advance, of which we have already some foreshadowing, will come on this side. And if I might without presumption venture a word of recommendation, it would be in favor of a more minute study of the simpler chemical phenomena.

Under the head of scientific mechanics it is principally in relation to fluid motion that advances may be looked for. In speaking upon this subject I must limit myself almost entirely to experimental work. Theoretical hydrodynamics, however important and interesting to the mathematician, are eminently unsuited to oral exposition. All I can do to attenuate an injustice, to which theorists are pretty well accustomed, is to refer you to the admirable reports of Mr. Hicks, published under the auspices of this Association.

The important and highly practical work of the late Mr. Froude in relation to the propulsion of ships is doubtless known to most of you. Recognizing the fallacy of views then widely held as to the nature of the resistance to be overcome, he showed to demonstration that, in the case of fair-shaped bodies, we have to deal almost entirely with resistance dependent upon skin friction, and at high speeds upon the generation of surface-waves by which energy is carried off. At speeds which are moderate in relation to the size of the ship, the resistance is practically dependent upon skin friction only. Although Prof. Stokes and other mathematicians had previously published calculations pointing to the same conclusion, there can be no doubt that the view generally entertained was very different. At the first meeting of the Association which I ever attended, as an intelligent listener, at Bath in 1864, I well remember the surprise which greeted a statement by Rankine that he regarded skin friction as the only legitimate resistance to the progress of a well-designed ship. Mr. Froude's experiments have set the question at rest in a manner satisfactory to those who had little confidence in theoretical prevision.

In speaking of an explanation as satisfactory in which skin friction is accepted as the cause of resistance, I must guard myself against being supposed to mean that the nature of skin friction is itself well understood. Although its magnitude varies with the smoothness of the surface, we have no reason to think that it would disappear at any degree of smoothness consistent with an ultimate molecular structure. That it is connected with fluid viscosity is evident enough, but the *modus operandi* is still obscure.

Some important work bearing upon the subject has recently been published by Prof. O. Reynolds, who has investigated the flow of water in tubes as dependent upon the velocity of motion and upon the size of the bore. The laws of motion in capillary tubes, discovered experimentally by Poiseuille, are in complete harmony with theory. The resistance varies as the velocity, and depends in a direct manner upon the constant of viscosity. But when we come to the larger pipes and higher velocities with which engineers usually have to deal, the theory which presupposes a regularly stratified motion evidently ceases to be applicable, and the problem becomes essentially identical with that of skin friction in relation to ship propulsion. Prof. Reynolds has traced with much success the passage from the one state of things to the other, and has proved the applicability under these complicated conditions of the general laws of dynamical similarity as adapted to viscous fluids by Prof. Stokes. In spite of the difficulties which beset both the theoretical and experimental treatment, we may hope to attain before long to a better understanding of a subject which is certainly second to none in scientific as well as practical interest.

As also closely connected with the mechanics of viscous fluids, I must not forget to mention an important series of experiments upon the friction of oiled surfaces, recently executed by Mr. Tower for the Institution of Mechanical Engineers. The results go far towards upsetting some ideas hitherto widely admitted. When the lubrication is adequate, the friction is found to be nearly independent of the load, and much smaller than is usually supposed, giving a coefficient as low as 1/1000. When the layer of oil is well formed, the pressure between the solid surfaces is really borne by the fluid, and the work lost is spent in shearing, that is, in causing one stratum of the oil to glide over another.

In order to maintain its position, the fluid must possess a certain degree of viscosity, proportionate to the pressure; and even when this condition is satisfied, it would appear to be necessary that the layer should be thicker on the ingoing than on the outgoing side. We may, I believe, expect from Prof. Stokes a further elucidation of the processes involved. In the meantime, it is obvious that the results already obtained are of the utmost value, and fully justify the action of the Institution in devoting a part of its resources to experimental work. We may hope indeed that the example thus wisely set may be followed by other public bodies associated with various departments of industry.

I can do little more than refer to the interesting observations of Prof. Darwin, Mr. Hunt, and Mr. Forel on ripplemark. The processes concerned would seem to be of a rather intricate character, and largely dependent upon fluid viscosity. It may be noted indeed that most of the still obscure phenomena of hydro-dynamics require for their elucidation a better comprehension of the laws of viscous motion. The subject is one which offers peculiar difficulties. In some problems in which I have lately been interested, a circulating motion presents itself of the kind which the mathematician excludes from the first when he is treating of fluids destitute altogether of viscosity. The intensity of this motion proves, however, to be independent of the coefficient of viscosity, so that it can not be correctly dismissed from consideration as a consequence of a supposition that the viscosity is infinitely small. The apparent breach of continuity can be explained, but it shows how much care is needful in dealing with the subject, and how easy it is to fall into error.

The nature of gaseous viscosity, as due to the diffusion of momentum, has been made clear by the theoretical and experimental researches of Maxwell. A flat disk moving in its own plane between two parallel solid surfaces is impeded by the necessity of shearing the intervening layers of gas, and the magnitude of the hindrance is proportional to the velocity of the motion and to the viscosity of the gas, so that under similar circumstances this effect may be taken as a measure, or rather definition, of the viscosity. From the dynamical theory of gases, to the development of which he contributed so much, Maxwell drew the startling conclusion that the viscosity of a gas should be independent of its density,—that within wide limits the resistance to the moving disk should be scarcely diminished by pumping out the gas, so as to form a partial vacuum. Experiment fully confirmed this theoretical anticipation—one of the most remarkable to be found in the whole history of science, and proved that the swinging disk was retarded by the gas, as much when the barometer stood at half an inch as when it stood at thirty inches. It was obvious, of course, that the law must have a limit, that at a certain point of exhaustion the gas must begin to lose its power; and I remember discussing with Maxwell, soon after the publication of his experiments, the whereabouts of the point at which the gas would cease to produce its ordinary effect. His apparatus, however, was quite unsuited for high degrees of exhaustion, and the failure of the law was first observed by Kundt and Warburg, at pressures below 1 mm. of mercury. Subsequently the matter has been thoroughly examined by Crookes, who extended his observations to the highest degrees of exhaustion as measured by MacLeod's gauge. Perhaps the most remarkable results relate to hydrogen. From the atmospheric pressure of 760 mm. down to about ½ mm. of mercury the viscosity is sensibly constant. From this point to the highest vacua, in which less than one-millionth of the original gas remains, the coefficient of viscosity drops down gradually to a small fraction of its original value. In these vacua Mr. Crookes regards the gas as having assumed a different, ultra-gaseous condition; but we must remember that the phenomena have relation to the other circumstances of the case, especially the dimensions of the vessel, as well as to the condition of the gas.

Such an achievement as the prediction of Maxwell's law of viscosity has of course drawn increased attention to the dynamical theory of gases. The success which has attended the theory in the hands of Clausius, Maxwell, Boltzmann, and other mathematicians, not only in relation to viscosity, but over a large part of the entire field of our knowledge of gases, proves that some of its fundamental postulates are in harmony with the reality of Nature. At the same time it presents serious difficulties; and we can not but feel that, while the electrical and optical properties of gases remain out of relation to the theory, no final judgment is possible. The growth of experimental knowledge may be trusted to clear up many doubtful points, and a younger generation of theorists will bring to bear improved mathematical weapons. In the meantime we may fairly congratulate ourselves on the possession of a guide which has already conducted us to a position which could hardly otherwise have been attained.

In optics attention has naturally centered upon the spectrum. The mystery attaching to the invisible rays lying beyond the red has been fathomed to an extent that, a few years ago, would have seemed almost impossible. By the use of special photographic methods Abney has mapped out the peculiarities of this region with such success that our knowledge of it begins to be comparable with that of the parts visible to the eye. Equally important work has been done by Langley, using a refined invention of his own based upon the principle of Siemens' pyrometer. This instrument measures the actual energy of the radiation, and thus expresses the effects of various parts of the spectrum upon a common scale, independent of the properties of the eye and of sensitive photographic preparations. Interesting results have also been obtained by Becquerel, whose method is founded upon a curious action of the ultra-red rays in enfeebling the light emitted by phosphorescent substances. One of the most startling of Langley's conclusions relates to the influence of the atmosphere in modifying the quality of solar light. By the comparison of observations made through varying thicknesses of air he shows that the atmospheric absorption tells most upon the light of high refrangibility; so that to an eye situated outside the atmosphere the sun would present a decidedly bluish tint. It would be interesting to compare the experimental numbers with the law of scattering of light by small particles given some years ago as the result of theory. The demonstration by Langley of the inadequacy of Cauchy's law of dispersion to represent the relation between refrangibility and wave-length in the lower part of the spectrum must have an important bearing upon optical theory.

The investigation of the relation of the visible and ultra-violet spectrum to various forms of matter has occupied the attention of a host of able workers, among whom none has been more successful than my colleagues at Cambridge, Profs. Liveing and Dewar. The subject is too large both for the occasion and for the individual, and I must pass it by. But, as more closely related to optics proper, I can not resist recalling to your notice a brilliant application of the idea of Doppler to the discrimination of the origin of certain lines observed in the solar spectrum. If a vibrating body have a general motion of approach or recession, the waves emitted from it reach the observer with a frequency which in the first case exceeds, and in the second case falls short of, the real frequency of the vibrations themselves. The consequence is that, if a glowing gas be in motion in the line of sight, the spectral lines are thereby displaced from the position that they would occupy were the gas at rest —a principle which, in the hands of Huggins and others, has led to a determination of the motion of certain fixed stars relatively to the solar system. But the sun is itself in rotation, and thus the position of a solar spectral line is slightly different according as the light comes from the advancing or from the retreating limb. This displacement was, I believe, first observed by Thollon; but what I desire now to draw attention to is the application of it by Cornu to determine whether a line is of solar or atmospheric origin. For this purpose a small image of the sun is thrown upon the slit of the spectroscope, and caused to vibrate two or three times a second, in such a manner that the light entering the instrument comes alternately from the advancing and retreating limbs. Under these circumstances a line due to absorption within the sun appears to tremble, as the result of slight alternately opposite displacements. But if the seat of the absorption be in the atmosphere it is a matter of indifference from what part of the sun the light originally proceeds, and the line maintains its position in spite of the oscillation of the image upon the slit of the spectroscope. In this way Cornu was able to make a discrimination which can only otherwise be effected by a difficult comparison of appearances under various solar altitudes.

The instrumental weapon of investigation, the spectroscope itself, has made important advances. On the theoretical side, we have for our guidance the law that the optical power in gratings is proportional to the total number of lines accurately ruled, without regard to the degree of closeness, and in prisms that it is proportional to the thickness of glass traversed. The magnificent gratings of Rowland are a new power in the hands of the spectroscopist, and as triumphs of mechanical art seem to be little short of perfection. In our own report for 1882 Mr. Mallock has described a machine, constructed by him, for ruling large diffraction gratings, similar in some respects to that of Rowland.

The great optical constant, the velocity of light, has been the subject of three distinct investigations by Cornu, Michelson, and Forbes. As may be supposed, the matter is of no ordinary difficulty, and it is therefore not surprising that the agreement should be less decided than could be wished. From their observations, which were made by a modification of Fizeau's method of the toothed wheel, Young and Forbes drew the conclusion that the velocity of light *in vacuo* varies from color to color, to such an extent that the velocity of blue light is nearly 2 per cent. greater than that of red light. Such a variation is quite opposed to existing theoretical notions, and could only be accepted on the strongest evidence. Mr. Michelson, whose method (that of Foucault) is well suited to bring into prominence a variation of velocity with wavelength, informs me that he has recently repeated his experiments with special reference to the point in question, and has arrived at the conclusion that no variation exists comparable with that asserted by Young and Forbes. The actual velocity differs little from that found from his first series of experiments, and may be taken to be 299,800 km. per second.

It is remarkable how many of the playthings of our childhood give rise to questions of the deepest scientific interest.

The top is, or may be, understood, but a complete comprehension of the kite and of the soap-bubble would carry us far beyond our present stage of knowledge. In spite of the admirable investigations of Plateau, it still remains a mystery why soapy water stands almost alone among fluids as a material for bubbles. The beautiful development of color was long ago ascribed to the interference of light, called into play by the gradual thinning of the film. In accordance with this view the tint is determined solely by the thickness of the film, and the refractive index of the fluid. Some of the phenomena are, however, so curious as to have led excellent observers like Brewster to reject the theory of thin plates, and to assume the secretion of various kinds of coloring matter. If the rim of a wineglass be dipped in soapy water, and then held in a vertical position, horizontal bands soon begin to show at the top of the film, and extend themselves gradually downwards. According to Brewster these bands are not formed by the "subsidence and gradual thinning of the film," because they maintain their horizontal position when the glass is turned round its axis. The experiment is both easy and interesting; but the conclusion drawn from it can not be accepted. The fact is that the various parts of the film can not quickly alter their thickness, and hence when the glass is rotated they rearrange themselves in order of superficial density, the thinner parts floating up over, or through, the thicker parts. Only thus can the tendency be satisfied for the center of gravity to assume the lowest possible position.

When the thickness of a film falls below a small fraction of the length of a wave of light, the color disappears and is replaced by an intense blackness. Profs. Reinold and Rücker have recently made the remarkable observation that the whole of the black region, soon after its formation, is of uniform thickness, the passage from the black to the colored portion being exceedingly abrupt. By two independent methods they have determined the thickness of the black film to lie between seven and fourteen millionths of a millimeter; so that the thinnest films correspond to about one-seventieth of a wave-length of light. The importance of these results in regard to the molecular theory is too obvious to be insisted upon.

The beautiful inventions of the telephone and phonograph, although in the main dependent upon principles long since established, have imparted a new interest to the study of acoustics. The former, apart from its uses in every-day life, has become in the hands of its inventor, Graham Bell, and of Hughes, an instrument of first-class scientific importance. The theory of its action is still in some respects obscure, as is shown by the comparative failure of the many attempts to improve it. In connection with some explanations that have been offered, we do well to remember that molecular changes in solid masses are inaudible in themselves, and can only be manifested to our ears by the generation of a to-and-fro motion of the external surface extending over a sensible area. If the surface of the solid remains undisturbed, our ears can tell us nothing of what goes on in the interior.

In theoretical acoustics progress has been steadily maintained, and many phenomena which were obscure twenty or thirty years ago, have since received adequate explanation. If some important practical questions remain unsolved, one reason is that they have not yet been definitely stated. Almost everything in connection with the ordinary use of our senses presents peculiar difficulties to scientific investigation. Some kinds of information with regard to their surroundings are of such paramount importance to successive generations of living beings, that they have learned to interpret indications which, from a physical point of view, are of the slenderest character. Every day we are in the habit of recognizing, without much difficulty, the quarter from which a sound proceeds, but by what steps we attain that end has not yet been satisfactorily explained. It has been proved that when proper precautions are taken we are unable to distinguish whether a pure tone (as from a vibrating tuning-fork held over a suitable resonator) comes to us from in front or from behind. This is what might have been expected from an *a priori* point of view; but what would not have been expected is that with almost any other sort of sound, from a clap of the hands to the clearest vowel sound, the discrimination is not only possible, but easy and instinctive. In these cases it does not appear how the possession of two ears helps us, though there is some evidence that it does; and even when sound comes to us from the right or left, the explanation of the ready discrimination which is then possible with pure tones is not so easy as might at first appear. We should be inclined to think that the sound was heard much more loudly with the ear that is turned towards than with the ear that is turned from it, and that in this way the direction was recognized. But if we try the experiment we find that, at any rate with notes near the middle of the musical scale, the difference of loudness is by no means so very great. The wave-lengths of such notes are long enough in relation to the dimensions of the head to forbid the formation of anything like a sound shadow in which the averted ear might be sheltered.

In concluding this imperfect survey of recent progress in physics, I must warn you emphatically that much of great importance has been passed over altogether. I should have liked to speak to you of those far-reaching speculations, especially associated with the name of Maxwell, in which light is regarded as a disturbance in an electro-magnetic medium. Indeed, at one time I had thought of taking the scientific work of Maxwell as the principal theme of this address. But, like most men of genius, Maxwell delighted in questions too obscure and difficult for hasty treatment, and thus much of his work could hardly be considered upon such an occasion as the present. His biography has recently been published, and should be read by all who are interested in science and in scientific men. His many-sided character, the quaintness of his humor, the penetration of his intellect, his simple but deep religious feeling, the affection between son and father, the devotion of husband to wife, all combine to form a rare and fascinating picture. To estimate rightly his influence upon the present state of science, we must regard not only the work that he executed himself, important as that was, but also the ideas and the spirit which he communicated to others. Speaking for myself as one who in a special sense entered into his labors, I should find it difficult to express adequately my feeling of obligation. The impress of his thoughts may be recognized in much of the best work of the present time. As a teacher and examiner he was well acquainted with the almost universal tendency of uninstructed minds to elevate phrases above things: to refer, for example, to the principle of the conservation of energy for an explanation of the persistent rotation of a fly-wheel, almost in the style of the doctor in "Le Malade Imaginaire," who explains the fact that opium sends you to sleep by its soporific virtue. Maxwell's endeavor was always to keep the facts in the foreground, and to his influence, in conjunction with that of Thomson and Helmholtz, is largely due that elimination of unnecessary hypothesis which is one of the distinguishing characteristics of the science of the present day.

In speaking unfavorably of superfluous hypothesis let me not be misunderstood. Science is nothing without generalizations. Detached and ill-assorted facts are only raw material, and in the absence of a theoretical solvent have but little nutritive value. At the present time and in some departments the accumulation of material is so rapid that there is danger of indigestion. By a fiction as remarkable as any to be found in law, what has once been published, even though it be in the Russian language, is usually spoken of as "known," and it is often forgotten that the rediscovery in the library may be a more difficult and uncertain process than the first discovery in the laboratory. In this matter we are greatly dependent upon annual reports and abstracts, issued principally in Germany, without which the search for the discoveries of a little-known author would be well-nigh hopeless. Much useful work has been done in this direction in connection with our Association. Such critical reports as those upon hydrodynamics, upon tides, and upon spectroscopy, guide the investigator to the points most requiring attention, and in discussing past achievements contribute in no small degree to future progress. But, though good work has been done, much yet remains to do.

If, as is sometimes supposed, science consisted in nothing but the laborious accumulation of facts, it would soon come to a standstill, crushed, as it were, under its own weight. The suggestion of a new idea, or the detection of a law, supersedes much that had previously been a burden upon the memory, and by introducing order and coherence facilitates the retention of the remainder in an available form. Those who are acquainted with the writings of the older electricians will understand my meaning when I instance the discovery of Ohm's law as a step by which the science was rendered easier to understand and to remember. Two processes are thus at work side by side, the reception of new material and the digestion and assimilation of the old; and as both are essential, we may spare ourselves the discussion of their relative importance. One remark, however, should be made. The work which deserves, but I am afraid does not always receive, the most credit, is that in which discovery and explanation go hand in hand, in which not only are new facts presented, but their relation to old ones is pointed out.

In making one's self acquainted with what has been done in any subject, it is good policy to consult first the writers of highest general reputation. Although in scientific matters we should aim at independent judgment, and not rely too much upon authority, it remains true that a good deal must often be taken upon trust. Occasionally an observation is so simple and easily repeated, that it scarcely matters from whom it proceeds; but as a rule it can hardly carry full weight when put forward by a novice whose care and judgment there has been no opportunity of testing, and whose irresponsibility may tempt him to "take shots," as it is called. Those who have had experience in accurate work know how easily it would be to save time and trouble by omitting precautions and passing over discrepancies, and yet, even without dishonest intention, to convey the impression of conscientious attention to details. Although the most careful and experienced can not hope to escape occasional mistakes, the effective value of this kind of work depends much upon the reputation of the individual responsible for it.

In estimating the present position and prospects of experimental science, there is good ground for encouragement. The multiplication of laboratories gives to the younger generation opportunities such as have never existed before, and which ex-cite the envy of those who have had to learn in middle life much that now forms part of an undergraduate course. As to the management of such institutions, there is room for a healthy difference of opinion. For many kinds of original work especially in connection with accurate measurement, there is need of expensive apparatus; and it is often difficult to persuade a student to do his best with imperfect appliances when he knows that by other means a better result could be attained with greater facility. Nevertheless it seems to me important to discourage too great reliance upon the instrument-maker. Much of the best original work has been done with the homeliest appliances; and the endeavor to turn to the best account the means that may be at hand develops ingenuity and resource more than the most elaborate determinations with ready-made instruments. There is danger otherwise that the experimental education of a plodding student should be too mechanical and artificial, so that he is puzzled by small changes of apparatus much as many school-boys are puzzled by a transposition of the letters in a diagram of Euclid.

From the general spread of a more scientific education we are warranted in expecting important results. Just as there are some brilliant literary men with an inability, or at least a distaste practically amounting to inability, for scientific ideas, so there are a few scientific tastes whose imaginations are never touched by merely literary studies. To save these from intellectual stagnation during several important years of their lives is something gained; but the thoroughgoing advocates of scientific education aim at much more. To them it appears strange, and almost monstrous, that the dead languages should hold the place they do in general education; and it can hardly be denied that their supremacy is the result of routine rather than of argument. I do not myself take up the extreme position. I doubt whether an exclusively scientific training would be satisfactory; and where there is plenty of time and a literary aptitude I can believe that Latin and Greek make a good foundation. But it is useless to discuss the question upon the supposition that the majority of boys attain either to a knowledge of the languages or to an appreciation of the writings of the ancient authors. The contrary is notoriously the truth; and the defenders of the existing system usually take their stand upon the excellence of its discipline. From this point of view there is something to be said. The laziest boy must exert himself a little in puzzling out a sentence with grammar and dictionary, while instruction and supervision are easy to organize and not too costly. But when the case is stated plainly, few will agree that we can afford so entirely to disregard results. In after life the intellectual energies are usually engrossed with business, and no further opportunity is found for attacking the difficulties which block the gateways of knowledge. Mathematics, especially, if not learned young, are likely to remain unlearned. I will not further insist upon the educational importance of mathematics and science, because with respect to them I shall probably be supposed to be prejudiced. But of modern languages I am ignorant enough to give value to my advocacy. I believe that French and German, if properly taught, which I admit they rarely are at present, would go far to replace Latin and Greek from a disciplinary point of view, while the actual value of the acquisition would, in the majority of cases, be incomparably greater. In half the time usually devoted without success to the classical languages, most boys could acquire a really serviceable knowledge of French and German. History and the serious study of English literature, now shamefully neglected, would also find a place in such a scheme.

There is one objection often felt to a modernized education, as to which a word may not be without use. Many excellent people are afraid of science as tending towards materialism. That such apprehension should exist is not surprising, for unfortunately there are writers, speaking in the name of science, who have set themselves to foster it. It is true that among scientific men, as in other classes, crude views are to be met with as to the deeper things of Nature; but that the life-long beliefs of Newton, of Faraday, and of Maxwell are inconsistent with the scientific habit of mind is surely a proposition which I need not pause to refute. It would be easy, however, to lay too much stress upon the opinions of even such distinguished workers as these. Men who devote their lives to investigation cultivate a love of truth for its own sake, and endeavor instinctively to clear up, and not, as is too often the object in business and politics, to obscure, a difficult question. So far the opinion of a scientific worker may have a special value; but I do not think that he has a claim, superior to that of other educated men, to assume the attitude of a prophet. In his heart he knows that underneath the theories that he constructs there lie contradictions which he can not reconcile. The higher mysteries of being, if penetrable at all by human intellect, require other weapons than those of calculation and experiment.

Without encroaching upon grounds appertaining to the theologian and the philosopher, the domain of natural science is surely broad enough to satisfy the wildest ambition of its devotees. In other departments of human life and interest, true progress is rather an article of faith than a rational belief; but in science a retrograde movement is, from the nature of the case, almost impossible. Increasing knowledge brings with it increasing power, and great as are the triumphs of the present century, we may well believe that they are but a foretaste of what discovery and invention have yet in store for mankind. Encouraged by the thought that our labors can not be thrown away, let us redouble our efforts in the noble struggle. In the Old World and in the New, recruits must be enlisted to fill the place of those whose work is done. Happy should I be if, through this visit of the Association, or by any words of mine, a larger measure of the youthful activity of the West could be drawn into this service. The work may be hard, and the discipline severe, but the interest never fails, and great is the privilege of achievement.

THE UNITY OF MATHEMATICS

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I. INTRODUCTION

EVERY successful work of art has unity: it is self-sufficient. Every particular work of art itself has unity. There is unity in architecture, in sculpture, in painting, in poetry, in music, in drama, in dancing, in mathematics. This unity is due to the central ideas which permeate the whole work. Works of art may be classified according to the objects with which they are concerned. Crosswise of this classification is that according to the central ideas which weave the objects together. The objects of mathematics may be arranged as numbers, figures, designs, harmonies, operators, algebras, processes and theories. Through these run the golden threads which unify them: Form, identity, invariance, dependence and ideality. Form exhibits the objects in some particular way; identity persists through all the changes in form; invariance is an identity in different objects; dependence is a net holding forms together; ideality is the source from which flow new objects. This is an ascending spiral which takes us to the level of a more expanded domain. These ideas are the life of mathematics, which produces its foliage and flowers.

Mind itself has these same ideas in its structure. From the shreds of experience we construct what we call the world. If we see it in a new light, from some new point of view, we still insist on its identity. Even before Parmenides philosophers were searching for the unchangeable essence of things. As things flowed into others, the ceaseless change emphasized by Heracleitos, dependencies or conditions were perceived, the mind needed the idea of functionality in order to organize the multitudinous swarms of consciousness. In the evolving forms of life creativity was at work in the natural world and the world of mind and spirit. New genii appeared. In the history of mathematics we find the record. And mathematics is so interwoven with life that its central ideas are also those of life. There is a unity of life and mathematics through these ideas. They are primeval gods, before all things and before the Fates. Born of chaos, they give birth to unity. They breathe life into the clay of isolated objects.

II. FORM

If we try to think of a world without forms, imagination fails. If the world were completely nebular, an aggregation of whirling particles moving in unpredictable and haphazard routes, shifting their positions rapidly and ceaselessly, with whimsical approaches and no less whimsical departures, lagging speeds, followed by lightning flashes; no electron structures, no atomic structures, no cells, no space configurations; an infinitely rapid whirlwind of changing elements; a universe of consciousness without memory, no vision, a dizzy, spinning madness of consciousness; being for an instant, an infinitesimal of time, followed by utterly unlike being for other instants; in such a universe what sort of ideas could there be, what type of thinking? It might be a pleasant, everlasting, forever changing nirvana of delight without form. But number would not exist, for there could be no individuals, everything would fuse together. Geometry would not exist, for all shapes would vanish in the making. Tactic would not exist, for there would be only disarrangements.

Logic would not exist, for there could be no conclusions. There might indeed be the realization of the will-o'-the-wisp of philosophers—"a succession of states of consciousness." Isolated instants can lead nowhere, for they can never be connected by the bonds of duration. Continuity would be absent, and each instant would become an infinitesimal eternity.

Irregularity and bizarre outlines do not prohibit form. The ceaseless dance of Brownian particles does not eliminate form. Even the gnarled and writhing trunks of trees on the timberline of some storm-twisted peak have common elements of form, as do the wisps of cloud that wind around their bases. But instantaneous and fleeting states do prohibit form. Form is found wherever there are static phenomena, and also in transitions that are orderly. There is form in the patterns of mathematics and also in its motricities.

Each art produces its characteristic forms. Modern art insists on the essential importance of form. In architecture the massive forms of Egypt, solid pyramids and huge blocks piled up expressed the immortality of life. The columns and roofs of Greece expressed the enjoyment of the present life. There is a suggestion in the buttressed Gothic cathedrals which we may well ponder to-day as the buttresses of organized churches are crumbling. The steel and glass towers in modern cities express the highly technical character of modern life. In municipal buildings and new homes we find many desert buttes and mesas, expressing the ever-resurgent appeal of nature to man. The pipes of Pan express simplicity of life, and the operas of Wagner express the emotional stress of civilization. The rainbow phantoms of mobile color come from an expanded consciousness, a new outburst of spiritual life. Hypernumbers, non-euclidean geometry, infinitesimals, discontinuous functions, gave man new liberties.

Forms may be classified as *irreducible, reducible, incidental, inclusive, synthetic, ensemble, limiting,* and others. An irreducible form is an element from which we may start in the construction of other forms. In multiplication a prime number is irreducible, and with the primes we may compound all integers. But on the additive side a prime of the form $4N+1$ is reducible, for it is the sum of two squares. Additively any integer is the sum of not more than four squares, nor the sum of more than nine cubes. In this way squares and cubes become irreducible elements, although some squares are the sum of two or three other squares, and some cubes are the sum of fewer than nine other cubes. The roots of Galois normal equations are irreducible elements in the sense that any one may be used to construct polynomials in it which will give every number in the field of the conjugate set of roots. A dance-form may be irreducible as the icosahedral group. A fugue may be reducible as the net of fundamental regions of an automorphic function.

As example of incidental form we will choose a method of reasoning due to Kempe. If we consider a collection of individuals, I, which can be separated into two exclusive sets, A and $\bar{A}$, and also into two exclusive sets, B and $\bar{B}$, we may construct a collection of the individuals in the incident sets, A,B, and those in the incident sets, $\bar{A},\bar{B}$. This collection we represent by $A*B$. For instance, let I be all integers, A the even numbers, $\bar{A}$ the odd numbers, B the multiples of 3, $\bar{B}$ those congruent to 1 or –1,modulo three, then $A*B$ consists of integers congruent to 0,1,or –1, modulo 6.

We find an inclusive form in some simple geometric diagrams. We may choose a point anywhere on each of two opposite sides of a paralellogram, join each to the two opposite vertices. The pairs of lines will meet in points which are on a line through the intersection of the diagonals. This is also true if we start with any quadrilateral, whether it has parallel sides or not. We may also choose four fixed points on a circle, ellipse, parabola or hyperbola, and two others anywhere on the curve, and we have a similar figure. In fact, all these forms are included in one, as particular cases of the Pascal hexagram. We find in analysis an inclusive form in the theory of linear operators, which gives a wide list of expansions. Finding inclusive forms is usually called generalization.

Metric geometry consists of synthetic forms, fusing together number and geometric form. Abstract groups synthesize the theory of integers and hypernumbers. An opera synthesizes the counterpoint of music and the action of a drama. The quatrains of Omar, the Mathematician, synthesize the fire of eternal youth and the ice of philosophy. Sandburg said that poetry is the achievement of the synthesis of hyacinths and biscuits. Realism is the synthesis of dreams and the rags of daily events. Idealism is the synthesis of aspirations and wisps of spiral nebulae. Actualization is the wedding of a beam of light and a chaos of dust-particles. Life knows how to synthesize creative spirit and the rhythms of wavicles. In the end all art is the synthesis of a vision and a medium of expression. The forms of mathematics are crystal flowers. Poetry creates silent music. Drama creates invisible rhythms. Architecture creates musical crystals. Sculpture creates sleeping life. Painting creates singing light. Color-music creates rainbow phantoms. Music creates ethereal flowers. Dancing creates radiant youth. Seraph and Merman may be wedded.

A limiting form is determined by an infinite or a very large collection. The characteristic curves of the differential equation $xdx + ydy = 0$ are an infinite set of concentric circles, which shrink upon the center as the limit form. The equation $xdy + ydx = 0$ gives an infinite set of rectangular hyperbolas which have as limit form the common perpendicular asymptotes. Mortality tables are limit forms from a very large number of individuals. Limit forms may have properties quite different from those of the determining set. A limit function determined by a set of continuous functions may be very discontinuous. A limit form may be included in the determining set or may be no part of it. The characteristic lines of a differential equation may be a system of straight lines and their envelope, or they may define other limit loci not given by the differential equation. Perhaps life, at least personal life, is a limit form tangent to, but not part of, the infinite succession of passing instants of being. Possibly Heracleitos had in mind the evanescent moving film of life, and Parmenides had in mind the limit form which we furnish as the real story. The flow of the swiftly vanishing present may be what we call subconsciousness, while consciousness is the accompanying limit form.

Form is the intellectual view we have of the particular mode of expression which the artist uses for his vision. He may change the medium and the form, leaving the vision the same. He may despair of ever finding an adequate expression for the beauty that haunts him. We can study the form he uses, which we usually call his style. Form itself has beauty. In the elegant presentations of Picard and Goursat analysis is beautiful. The aeroplane views of Klein, with wide horizons, and the swift intuitive penetrations of Poincaré to the heart of the problem are two types of beauty. Beauty should find her incarnation worthy of her, whether in mathematics or in life.

III. IDENTITY

Form may change without a change in the object. There is an underlying identity. This is a frequent device in poetry. John Gould Fletcher says:

> Like spraying rockets
> My peonies shower
> Their glories on the night.
> Towards the impossible,
> Towards the inaccessible,
> Towards the ultimate,
> Towards the silence,
> Towards the eternal,
> These blossoms go.

In this he repeats in different forms the futility of expression in actualizing a spiritual insight. A wild-bird's cry and the beat of the sea may also take the form of a dance-ecstasy. A majestic procession of clouds across the sky may be identical with a nocturne of Debussy. Georgia O'Keeffe's "Music—black, blue, and green" is identical with an ecstatic rhapsody.

Twenty-four centuries ago Parmenides, poet-philosopher, insisted that what really is always has been and always will be. He said the never-ceasing flow of the philosophy of Heracleitos was an illusion. The real is permanent and abiding. Its protean forms merely veil the eternal identity. Modern philosophy is in confusion: for, while it insists upon the permanence of a substance variously called matter, energy, electron, positron, neutron, etc., yet it actually considers only a series of vanishing events, a swiftly changing film of happenings. If we return to the arts, we find they are expressing in some temporary form a reality called beauty. Beauty is not a thrill, it is a definite spiritual reality, every work of art expressing rhythm, order, symmetry, harmony, with form, identity, invariance, functionality and ideality shining through. In a dance we find

> An evanescent pattern on the sight,
> Beauty that lives an instant, to become a sister
> beauty and a new delight.

Mathematics would be nearly helpless without identities. We transmute our statements into other forms which will be more easily penetrated. Many theorems are of this nature. An isosceles triangle is also isogonal; four points joined in pairs, so that the two joins are equal and bisect each other, may also be joined so as to make a rectangle. A polyhedron with four vertices is a polyhedron with four faces. If we construct a rectangle divided into four equal rectangles, and around the center place four points symmetrically, we may repeat this diagram all over a plane. It is identical with the design of the important points of an elliptic function, and also with the design of an electric distribution produced by an infinite charged wire enclosed by an infinite rectangular prism of conducting material. Again if we consider the algebra of the Kempe triadic logic, we find it is identical with the algebra of a group generated by an infinity of commutative operators of order 2. This Kempe logic includes the usual logic of classes and propositions, but is more general, for in it we have expressions that represent collections X which consist of common elements of A and B, but we do not know whether or not there are any elements from $\bar{A}$ or $\bar{B}$. In the ordinary logic it is assumed that a collection I can be exactly split into collections A and $\bar{A}$, B and $\bar{B}$, which also means into AB, $\bar{A}B$,$A\bar{B}$,$\bar{A}\bar{B}$. Any collection considered is definitely known to include one or more of these and to exclude the others. But in the Kempe logic we may have a collection X known to include one or more of these, but it is not known if it excludes or includes the others.

Cayley designed colored linkages whose routes would give an identical representation for any abstract group. As an example let us take the quaternion group which has eight members, given by combinations of A and B, where $A^4 = 1 = B^4$, $A^2 = B^2$, $BA = A^3B$. To make the diagram we use the edges of a cube. Those of the upper face are traversed positively and may be colored yellow. The lower face has its edges colored yellow also and is traversed negatively as seen from above. The vertical edges are colored blue and traversed downwards. The diagonals are also colored blue and traversed from the bottom point towards the top. If we put in the diagonals of the faces, colored white, they will give AB or BA. Whatever vertex is used as the beginning, the quaternion group is completely represented by this linkage.

Identities are *heteromorphisms, automorphisms, isomorphisms, equivalences, conjugacies,* and others. A song without words is a heteromorphism. The statues of Aphrodite are automorphisms. Different ballet dances are isomorphisms. The temples of Philae, of Brahma, the cathedrals of Europe, the mosques of Morocco, are equivalent forms. If we express the irrationals of a Galois field in terms of one of the roots of the normal equation, the same expressions will serve to represent the field of irrationals in terms of another of the roots, but not the same irrationals. In conjugate forms the expressions based upon one element of the conjugate set are also expressions when the base is a different conjugate element. There are conjugate dance forms. In an equivalence the identity is in some property. Modulo 12 we may consider as equivalent 5,17,41. Every equivalence can be called a congruence. Isomorphism gives us a form different from the original but of identical significance. The Wedding March of Lohengrin is isomorphic to the Wedding March of Mendelssohn. The Ave Maria of Brahms is isomorphic to the Ave Maria of Schubert. An automorphism is an identity of form. For instance, 65 is the sum of two squares in two automorphic ways, 1^2+8^2 and 4^2+7^2. The cyclic group of order 8 may be generated by the powers of either A, A^3, A^5 or A^7.

Heteromorphisms are perhaps the most difficult to discover. We would not at first think of any connection between Kempe's logic and synthetic geometry in a plane. But Kempe shows that if we read $A*B=C$ as "C is between A and B," every theorem in the logic becomes a theorem in the synthetic geometry of intersections in a plane. The value of the use of vector algebra in relativity theories lies in the heteromorphism by which every product and every sum in the algebra corresponds to a law or an object in the physical theory. If this is known many theorems can be enunciated without experimental proof. Sometimes heteromorphisms in mathematical theories are called "interpretations," and if such a new interpretation is found we at once have an extensive addition to our knowledge.

Art creates heteromorphisms. The metaphor expresses a heteromorphism. Sandburg expresses an identity when he says: "Poetry is the tracing of a finite sound to the infinite point of its echoes." Mathematics is the tracing of a single instance to the infinite point of its echoes. Mathematics writes the music of the spheres, as Pythagoras said. Mathematics paints with the colors of endless spectra. Mathematics recites the odyssey of human thought, as shown by Brunschvig. Mathematics follows the rainbow to the pot of gold. Hypernumbers are ripples of consciousness expanding into an infinite universe. Processes create new reasonings out of the chaos of ideas. Descartes showed the identity of algebra and geometry, and Lie the identity of continuous groups and differential equations. Poincaré perceived in his study of automorphic functions their identity with non-euclidean geometry. Linear algebras show the identity in the structures of expansions in fundamental functions. Sylvester and Kronecker agreed on the identity of mathematics and poetry.

Form is a golden thread that weaves together the objects of life. Identity too is a golden thread that weaves together the objects of life. Life is the process of maintaining an identity. Human personality is an identity.

> Think, then, you are Today what Yesterday
> You were—Tomorrow you shall not be less.

Not a goddess only has the inscription:

> I am that which is, has been, and shall be.

IV. INVARIANCE

Invariance is the property an object has of remaining unchanged, although it is connected with another object that does change. In the tempered scale of music the numerical relations between the vibration numbers of the tones of a major chord or a minor chord remain unchanged whatever the dominant note. In a fugue the theme remains the same through all its various expressions. We are usually taught that we should develop an invariant character, one which through all vicissitudes is solid, unchanging, "to be depended upon." The flowing cloud which Stuart Pratt Sherman insisted upon as the ideal character, and the eternal youth that Omar talks about, are not invariant characters, at least not in the conventional sense. The philosopher's search for final and all-comprehending truth is a quest for the invariants of life. So far as we know, there are none. Perhaps the only invariant of life is the everlasting quest itself, and a universe built on invariants would soon be frozen into silent death. Even laws of physics can depend upon the time functionally, and are not invariant.

A differential equation has characteristic lines, and these are invariant. The equation $xdy - ydx = 0$ has for its lines the radii from the origin in all directions in the plane of x, y. If we change the variables to r and θ, it becomes $d\theta = 0$, giving the same lines. The parallelograms that circumscribe an ellipse have an invariant area. If we cut a circle by secants through a fixed point, the product of the segments is an invariant for all secants. As a line moves in Euclidean space its length is invariant. The sum of the angles of a plane triangle is invariant, but not so on a sphere. The prime factors of an integer are the same set, in whatever order they may be found.

Invariants may be *parts* of the changing objects, *properties* of it, *related objects* or *fundamental objects.* If we express quaternions in terms of i, j, k and then change to a new expression in terms of i′, j′, k′, the scalar and the tensor of the quaternion will remain the same. These are *parts* of the quaternion. If we multiply an integer of the form $a^2 + b^2c$ by another of the same form, the product is also of the same form, which is an invariant *property.* If we transform a matrix by a non-singular matrix, the scalar coefficients of the Cayley-Hamilton equation are *related* invariant forms, which may be calculated from the constituents or coefficients of the matrix transformed.

The axioms, postulates and other basic forms upon which a branch of mathematics depends are fundamental, and are invariants. The basis for Euclidean geometry remains unchanged throughout its development. Sometimes we see the statement that mathematics is a vast tautology, all its theorems being merely restatements of the fundamental bases. But actually the theorems state much more than the bases. There is a synthesis involved. Klein in his Erlanger Programm asserted that any geometry is really the statement of the invariants of a particular group. But Klein did not mean to imply by this that the discovery of these invariants was a simple matter and of no great importance. He well knew the difficulties in developing a geometry, even if the group was given. It has taken centuries to arrive at the theorems of to-day in Euclidean geometry. Even the geometry of trilinear coordinates, called by Tait an "elegant trifle," is open for many new theorems. An abstract group is something different from its incarnation in a Galois group. The polynomial operators which give us the forms for the conjugate roots in terms of a given root are not easy to find. Consider the group given by the equations $A^{10} = 1 = B^8$, $BA = A^3B^5$. It is quite elementary in its properties, but what are the 80 expressions for the roots of its normal equation in terms of a selected one? We may write out without much difficulty the groups of order 32, but what are their normal equations? A simple test by any one will convince him that a set of postulates arbitrarily given is far from giving a developed theory corresponding. Merely to give a basis for a theory is just as inadequate for the theorems as the construction of a foundation for a cathedral is for the sublime structure erected upon it.

Sometimes invariants are considered to be significant of objective realities. Geometric invariants correspond to geometric objects. Physical invariants correspond to physical objects. Biological invariants give us natural laws. Authority has long been an invariant of society with an objective power back of it: yet to-day it is vanishing and equality is taking its place. Belief in God or gods has been invariant in the race; does it mean an objective reality? Does human personality also create new groups in different eras to furnish new invariants? Where are the snows of yesteryear?

V. FUNCTIONALITY

Classical philosophy was concerned with the ideas we have considered thus far. Pythagoras was interested in the structure of all things as made of numbers. Parmenides was interested in identity. Plato's ideas were universal invariants. Heracleitos mused over the ceaseless flow, the becoming of things, the philosophy of change. In recent times this has been profoundly developed by Bergson. Modern science started a new philosophy: that of functionality, which includes "becoming." Science tries to determine the necessary conditions that underlie phenomena and hopes to arrive at sufficient conditions. Too often a necessary condition has been considered as sufficient. When it was found that certain glandular actions seemed to be necessary to the development of some of our human characteristics, it was hastily stated that they were sufficient. Heredity and environment are among the necessary conditions of life. Are they sufficient to account for Plato, Da Vinci, Shakespeare, Beethoven, Poincaré? Human personality is a function of heredity, physiology, environment—and of nothing else? Psychological events are functions of nervous events—and are there no other variables? What if in the flow of life there are no sufficient conditions, and, as Heracleitos asserted, we never step into the same stream twice!

One type of functionality is *correlation*, that of my shadow, which goes in and out with me. This is the relation of a projected figure to the initial figure. Reciprocation is also a correlation. If we find with reference to a fixed triangle the polars of three points, they make a triangle whose vertices will have the lines through the three points as polars. If we arrive at the original triangle this way, so as to have a self-polar triangle, we have an involutory correlation. An ideal romance is an involution. Correlation of human lives is called "getting adjusted to society."

Limit forms are functions of an *infinity* or a great *multitude* of variables. The calculus of variations and Volterra's functions of lines are of this kind. Social structures are limit forms arising from very many individuals. A cloud is a statistical function of a multitude of miniature balloons. The mortality curve is a function of 100,000 individuals. Moral laws are the compromises of courses of action of various myriads of persons. Laws of physics to-day are statements of probabilities of what will happen in the interplay of a great number of whimsical particles. The past and the future, immediate and remote, condensed with the present, subjected to all the variations of differing individuals, give us a limit function called the norm, or law, of history. Life is the limit function of a rapidly arriving and dissolving cinema film, threaded on the fibers of the universe, suffused with the color of creative desire.

Dominant functions furnish values below which or above which lie the values of another function. For rapidly oscillating functions, dominant functions become very important. They have more latitude than limit functions. The dominants of certain sets of human actions are extremes of action which the actual actions may never reach. Those whose actions cross outside the dominant are called insane, criminal, fanatic or genius. The prediction of dominant functions of human action becomes necessary to all who would sway mankind.

Nascent functions are those of Heracleitos's "becoming." The events of the present moment determine those of the next moment. This is the type of functionality expressed in differential equations. The rate of inversion of sugar is in proportion to the amount still uninverted. Cooling has a rate determined by the temperature already attained. The next movement of the dancer is the outcome of the movement just finished. It has sometimes been assumed that in natural phenomena events were governed by nascent functions. Given a complete description of positions and velocities (and we may add, accelerations and fields) of all particles in the universe, we might thence determine forwards what the universe would be in 10000 A.D., or equally backwards, what it was in 10000 B.C. This kind of functionality is assumed by all who believe that dreams foretell coming events. Every instant is pregnant with what will be born the next instant. No undetermined event can happen. This deterministic view is opposed of course to that of creative evolution, which sees entirely new causes and results emerging.

Opposed to this philosophy we find on one hand physics, which has to discuss functions in which the events of tomorrow depend on those of to-day, but also on those of the yesterdays, in a direct way, and different from the mediation of time in between. What a non-magnetized piece of iron will do depends upon its history. Day before yesterday is not dead and buried, but reaches across today with ghostly fingers to affect tomorrow. The grandfathers eat sour grapes and the grandchildren's teeth are set on edge.

Biology contributes its opposition along with physics. Life depends upon more elements than heredity and environment. There are mutations which can not be thus accounted for. Some of these may be produced artificially by the action of the human intellect in arranging extraordinary conditions, like great heat or cold or x-rays. But the mere fact that it takes a keen laboratory experimenter to do this proves that impersonal environment and heredity were not sufficient. The most important conclusion of modern science is that we can never account for events by the data we are able to get. If we are so blind as to assume that we could succeed "if we knew all the data," the "appeal to ignorance," then we are too blind to do scientific work.

A most important functionality is *freedom* and the *creative* relation. A vision beckons us from the future. A nocturne of Debussy may scintillate with aspirations. A dance of Ruth St. Denis is a prophecy for the race. The monads of Leibniz will grow into a new calculus. Goldbach's conjectured theorem is a call for another theory of integers. The hypernumbers of Dirac project physics into the relativity universe. Orthogonal functions lead to wave-mechanics. Quaternions took Hamilton into a new world of hypernumbers. Operational analysis was the guide for Heaviside through a wilderness. The martyr and the fanatic are functions of the future. To say that human actions are solely governed by the past is to ignore the most important things humans have done. Human action for to-day only is called opportunist, blind, short-sighted. There are also functions that are beyond the reach of time, are eternal, supernal. Functions, too, are golden threads of the web shot through the universe to hold it together.

VI. IDEALITY

This is the most important central principle. Through it mathematics becomes a fairy-land, where Merlin waves the magic wand, and strange new things come upon the stage. These are not evolutions from what went before, but are produced by a creative activity. They do not arise from any of the data of the senses. When long ago an unknown genius said, "let there be negative numbers," they were so far removed from sense experience that for centuries they were called fictive, and "people did not approve of them." They said: "How can numbers be less than nothing?" Later another genius said: "Let there be square roots for negative unity," and these are still called "imaginary." When the law of unique factorization needed to be extended to algebraic integers, Kummer said, "Let there be ideal numbers," and so it was. Lobachevsky said, "Let there be a geometry with many parallels through a point," and it came to pass. Riemann said, "Let there be no parallels," and it was so. Then Riemann waved his wand again and an infinity of new geometries based on infinitesimals came into existence, and these fictions are used to-day in the relativity theories to explain very real phenomena. Hamilton said, "Let there be endless imaginary numbers," and so it was. Fourier said, "Let there be expressions for functions made up of arbitrary pieces," and the theory of expansions began. Weierstrass said, "Let there be continuous non-derivable functions," and now we are far from the use of the eye in studying graphs. If electrons have positions determining such functions the whole of physics has to be rewritten. Darboux said, "Let there be discontinuous functions which between $x=a$ and $x=b$ will take every value between $f(a)$ and $f(b)$," and so it is. Peano said, "Let there be functions which will ultimately give every point inside a square," and we study them. Transcendentally crinkly curves are very curious. Brouwer said, "Let there be numbers which are neither rational nor yet irrational," and logic has been deprived of the law of excluded middle. We have seen logics created in which the law of identity has vanished. There are logics in which the law of contradiction has also gone. We have in every case been forced to revise our methods of thinking. And in every case the magic wand has created new beings which have dissolved complications of thought, removed absurdities and contradictions. The law of contradiction made it impossible to think of beings which were material and at the same time immaterial. Yet spirit and mind are just that. Freedom and determinism have to be attached to the human being, it has both qualities. We must think in terms like these or we end in dismay. We see the universe in a new light, we dispense with red rays and pass to yellow rays, blue rays, ultraviolet rays, x-rays, cosmic rays. Electrons and protons are both particles and wave-phenomena. Matter and energy have merged. Clouds of particles may have laws but particles are whimsical. Everything is swiftly losing its identity and becoming something quite different. The cat has vanished, leaving only the grin.

Ideal objects arise sometimes from the creation of a *new class* which will make complete the possibility of solving an equation. This is a closure property. With algebraic irrationals and with complex numbers we may find roots for any algebraic equation in one variable x. With hypernumbers we can solve equations which have variables x, y, etc. A solution of $z^2 - 2wz + w^2 + x^2 + y^2 + z^2 = 0$ is the quaternion $z = w + ix + jy + kz$. Galois ideals solve congruences. Points at infinity, imaginary points, lines at infinity, four-dimensional and N-dimensional geometries enable us to fill out our problems in space. Poincaré pointed out the rôle physics has played in suggesting new mathematical objects. Whenever Antaeus touches the earth he gains new strength.

Ideal objects may also be *direct creations* of a new and perhaps unwanted order. The infinitesimals of Leibniz are still objects of suspicion to many mathematicians. Non-Archimedean arithmetic is to be developed. The theory of integers needs new ideas for its ordering. Elements of real and not arithmetic continuity must be studied. What vistas will open to psychology when the mathematics of duration is developed? The vast regions of processes have not been visited. Of the 5 types of commutativity only one has been considered, and of the 175 types of associativity in general fields, only one is studied.

Merlin has been bound at various times by Viviane, who has used the logic Merlin himself created to knot him with cords. She is powerless, however, for whenever he thinks a new world, a new creation, with new laws and new objects, the old world ceases to be a prison. The ant that runs around inside a circular band is a prisoner, until he leaves his plane and goes into the third dimension over the prison wall into a new space. So long as mathematicians are enchanted by the magic formula, "Mathematics is symbolic logic and nothing else," so long is Merlin a prisoner. But when he calls upon the Queen of Beauty for new worlds he is set free.

For truly, as thou sayest, son, a Fairy King
And Fairy Queens have built the city, son;
They came from out a sacred mountain-cleft,
Towards the sunrise, each with harp in hand,
And built it to the music of their harps.

For, an ye heard a music, like enow
They are building still, seeing the city is built
To music, therefore never built at all,
And therefore built forever.

Life seizes time and space, the rhythm of energy and the flames of inspiration, weaving them into a rhapsody of music. Ideality is the living cord which creates the past, present and eternity. Dreams as imaginary as the square root of -1 or as fantastic as relativity space and time, are to-morrow powerful actualities. Life consists in the creation of ideal objects.

The primeval gods were born of chaos, but their immense power is hurrying the particles of chaos and the ripples of its ocean, its intense fields and its creative spirits, into the unity of a universe. Through the ages of human life mathematics has come to be the screen upon which we may glimpse this unity.

NATIONAL TRENDS IN NOBEL PRIZE AWARDS[1]

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THE Nobel prize awards for 1936 which aroused much interest were:

Physics: joint award, Victor Franz Hess, Innsbruck University, Austria
Carl David Anderson, California Institute of Technology, Pasadena
Chemistry: Peter Joseph Wilhelm Debye, Kaiser Wilhelm Institute, Berlin
Physiology and Medicine: joint award, Otto Loewi, University of Graz, Austria
Henry Hallett Dale, Director, National Institute for Medical Research, London
Literature: Eugene Gladstone O'Neill, Sea Island, Georgia
Peace: Carlos Saavedra Lamas, Argentina

Besides these an award of the 1935 Peace Prize to Carl Ossietzky, a German, was also made.

When Alfred Bernhard Nobel, Russian chemist and manufacturer, provided in his will that the income from eight million dollars be used to award prizes in five fields of endeavor "without any regard to nationality" he established a yardstick of national achievement. Nobel died in 1896, and annual awards have been made by designated groups of distinguished Europeans since 1901 in the five fields of physics, chemistry, physiology and medicine, literature and peace.

Had an award in each field been made each year the total would now be 180. But in some years an award in a special field or fields has been omitted, so that the number through 1936 is 155. These have been distributed as shown in Table I.

Nineteen nations are represented, Argentine being the newest member of the group.

TABLE I
NATIONALITY OF NOBEL PRIZE WINNE
1901–36

Country	Physi	Chemistry	Physiology Medicine	Literature	Peace	Awards	
						1901–18	Total
Germany	10	14	6	5	2	20	37
England	7	4½	3½	3	3½	9	21½
France	4	4	3½	4½	3½	11½	19½
United States	3	3	4	2	5½	5	17½
Sweden	2	2½	1	3	2	5½	10½
Switzerland	1	1	1	1	2½	4½	6½
Holland	3	1	1½	..	½	4½	6
Denmark	1	..	3	1	½	2½	5½
Austria	½	1	2½	..	1½	2½	5½
Belgium	..	..	1	1	2½	3½	4½
Norway	..	..	..	3	1½	1	4½
Italy	½	..	½	3	½	2½	4½
India	1	..	..	1	..	1	2
Poland	..	..	..	2	..	1	2
Russia	..	..	1	1	..	1	2
Spain	..	..	½	1½	..	1	2
Canada	..	..	1	..	..	..	1
Ireland	..	..	..	1	..	..	1
Argentina	..	..	..	..	1	..	1
International	..	..	..	..	1	1	1
Total	33	31	30	33	26	77	155
Distribution	10	8	14	15	14	16	18

All true science, literature and peace are international in scope. From a world view-point, then, it is interesting to ask what are the national trends in these awards. These may be seen in the graphs of Fig. 1, showing the cumulative percentages of total awards made, received by the four nations leading in number of awards.

Germany's preeminence is evident, and it is significant that the German percentage line has never been below 20, holding steadily between 20 and 28 of the total for 34 years. England likewise has maintained a steady percentage on a lower level than Germany, there being a slight upward trend from the low of 10.3 per cent. in 1914. For many years the percentage of France was next to that of Germany, but a slight downward trend

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[1] See SCIENTIFIC MONTHLY, Vol. XL, pp. 167–169, February, 1935.

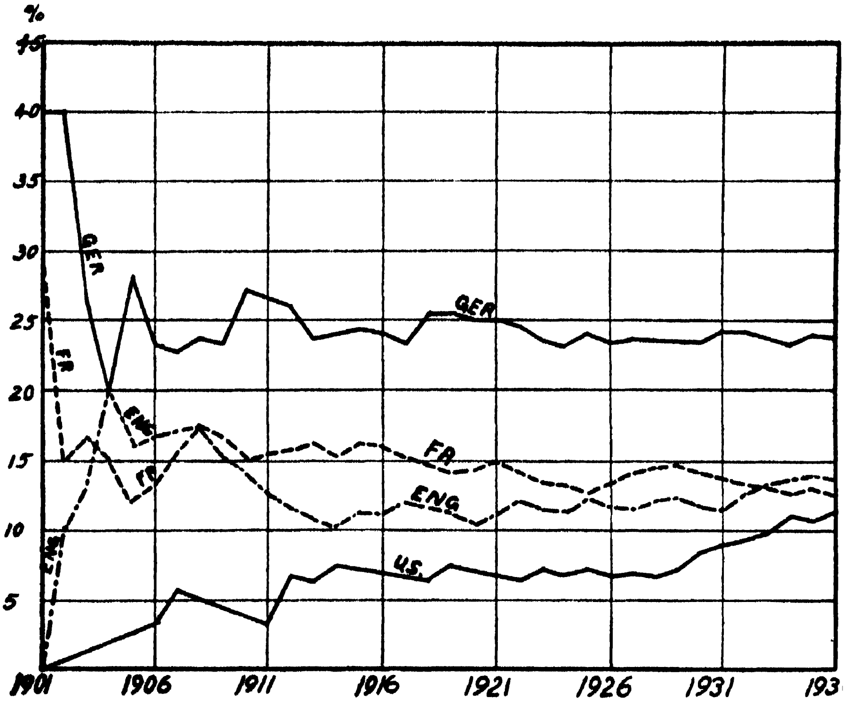

%
45
40
35
30
25
20
15
10
5
GER
FR
ENG
GER
FR
ENG
FR
ENG
U.S.
1901
1906
1911
1916
1921
1926
1931
193

FIG. 1

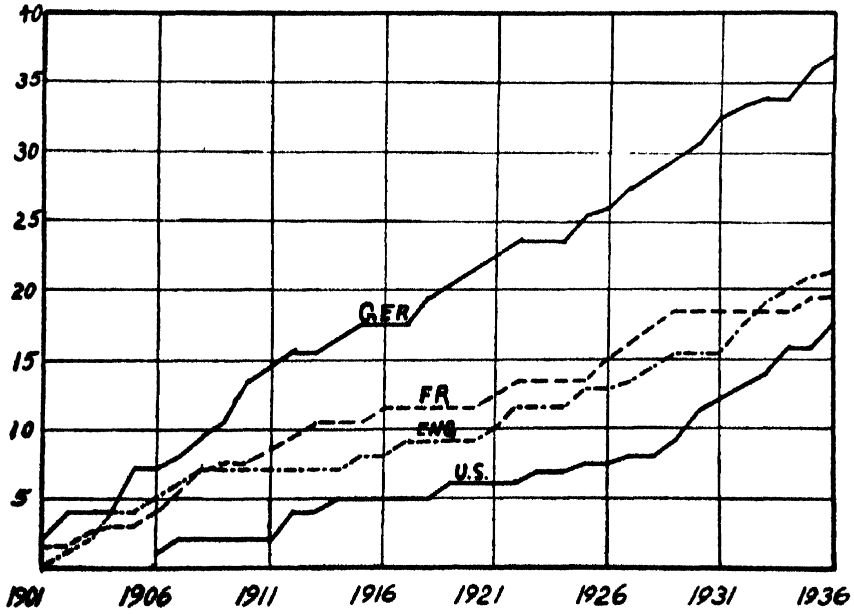

40
35
30
25
20
15
10
5
GER
FR
ENG
U.S.
1901
1906
1911
1916
1921
1926
1931
1936

FIG. 2

has brought the curve below that of England.

The United States won no prize in the first five years until the award for Peace was made to Theodore Roosevelt in 1906. In 1911 its percentage was only 3.6, but since then the percentage has been higher, the trend being decidedly upward in the last eight years.

Another view-point of these awards is shown in the total number of Nobel prizes awarded to each of the four leading nations (Fig. 2).

The steady rise of the German line is impressive. The same is true of the lines for England and for France, but the rise is more gradual and not so regular and the absence of French awards from 1929 to 1934 causes the lines to cross. The original position of the United States in the early years was not only below Germany, France and England but below others also. As late as 1911 more awards had gone to Holland, Sweden, Switzerland and Italy as well. Awards had been made to twelve nations before such recognition came to America in 1906. Several horizontal periods of years of no award are evident. But recently its curve of awards rises rapidly.

In Table II of total awards over different periods it is seen that: (1) the United States has risen from a low fifth in the total awards in 1918 to a very close fourth in 1936; (2) since the world war as many awards have been made to Americans as to Englishmen, only those to Germans being greater; and that in awards made during the past eight years the United States has been the leader.

TABLE II
TOTAL AWARDS OVER DIFFERENT PERIODS

	Entire 1901–36	1901–18	1918–36	1929–36
Germany .	37	20	17	8½
England ..	21½	9	12½	7
France ...	19½	11½	8	2
U. S. A. ..	17½	5	12½	9½
Sweden ..	10½	5½	5	1½

THE BRAIN FROM FISH TO MAN. II

A SERIES OF CULMINATING PHASES IN EVOLUTION

By Dr. FREDERICK TILNEY

PROFESSOR OF NEUROLOGY, COLUMBIA UNIVERSITY

THE BRAIN OF MAN

Although the human brain has made great advance in its weight when compared with the anthropoid brain, both absolutely and in relation to body weight, its chief superiority lies in the intricate complexity of its convolutional arrangement. The richness of its convolutions provides for a far more extensive spread of the neocortex. Its fissural pattern is more conspicuously Rolandic than in the anthropoids, but above all else is the obvious superiority of the frontal lobe. Superiority in this region of the neocortex carries with it what amounts to a new mastery of life. It is in this part of the brain that there gradually has emerged a cortical area essential to speech which in conjunction with other emergent areas in certain other regions of the cortex is essential to spoken language. Here also the neocortex makes more ample provision from the production and control of a greater, a more complex, a more highly potential range of skilled acts, which, like speech, may be regarded as something new in the animal kingdom. Or, if the newness of these acquisitions should be questioned, it is certainly true that they have done not a little to change the face of nature, to contend with forces which heretofore had not been challenged and to institute organizations, both material and spiritual, which are dependent upon the hand and brain of man. Properly speaking, this new mobilization of motor capacity, called neokinesis, should not be limited to the human race. In the strict sense it is the outgrowth of the neocortex and hence a characteristic of the mammal. But that it has had its culmination in man, as shown in the development of his many skilled activities and above all in his speech attainments, there can be no doubt.

The frontal lobe, often referred to clinically as a silent area of the brain, as a matter of fact is to be credited with most outspoken functions, not merely in the sphere of speech but in certain even more subtle attributes such as those connected with the regulation of the higher faculties, the development of the personality and the formation of all those associational memories which enter into personal experience and thus bespeak the degree of intellectual attainment. A similar and comparable convolutional expansion occurs in the occipital, parietal and temporal lobes of the human brain. These are features distinctive of man. But the accessions in the frontal region of the human cerebrum, in size, in prominence and in convolutional complexity overshadow all other advances. When, in the course of time, the brain has reached this level of evolutionary progress, the secret of its success in humanity was not alone that it had set on foot the Age of Man but far more that it had made possible an Age of the Frontal Lobe (Fig. 17).

NEOCORTICAL HORIZONS OF THE PRIMATES

All these advances, leading up to man and culminating in his preeminence, took place in a single favored order, the primates. It was not because other orders in the great and essentially progressive class of mammals were lacking in the endowment of an ample neocortex that they failed to climb to the top.

Many of these other orders have most impressive looking hemispheres. But the neocortical design which failed to make ample provision for the frontal lobe was deficient in its ultimate prospects. Undoubtedly the primates' mode of living was provocative in making such provisions, for it must be apparent that the effect of arboreal habits had much to do with the development of the hand. The manner in which tree-life favored the development of hands and the erect posture is no longer a matter of debate. It is susceptible of exact demonstration. Whatever may have been the influences which caused certain members of the prehuman stock to desert the trees and live upon the ground, it is clear that one most important result of this change was the formation of the human foot. This structure was a solid foundation for the highest achievements of organic evolution. It ultimately produced an animal capable of dominating the world. It was responsible for all the extensive changes incident to the erect posture, for the rearrangements in the shape of the body, for the squaring of the shoulders and the broadening of the pelvis, for readjustments in the position of the heart and lungs, for new provisions in supporting the abdominal organs, for a reordering in the relation of the eyes to provide binocular, stereoscopic vision, for the modifications in the neck to suit the purposes of the most effective head movements, for freeing of the hands so that they might become highly constructive agents and, above all, for impressing upon the brain the effects of these many progressive advantages. If there could be any doubt that the hand and foot contributed in this decisive manner to the development of the brain, it might be asked, what would the brain have been if neither hand nor foot had made its appearance? It is apparent what limited advantages were acquired by animals equipped with hoofs or paws, flippers or wings. The brain responded to the requirements of these specialized organs. Nevertheless, such response was always and unmistakably the brain of an ungulate or a meat-eater, of a flying or of a swimming mammal. It was the brain of an animal of restricted behavior, as limited in the development of its intelligence as it was in the amplitude of its adjustments to life. It was particularly deficient in one great brain division which is the hallmark of all animals possessing hands. Summarized as briefly as possible, it may be said that what the brain owes to the hand and foot is the frontal lobe.

The history of the primates shows that they represent at least five definite horizons of progress. Beginning with Tarsius and Lemur, the Rolandic pattern first becomes apparent. The establishment of this pattern is accompanied by the earliest indications of the region forming the frontal lobe which, from this time onward, continues to gain in prominence. Going hand in hand with these advances, there has been a progressive intensification of functional localization in the neocortex. However diffuse such localization may have been in the cortex of lower mammals or even in the lower primates, there can be no question but that it became more and more precise in passing from one horizon to the next higher one. It is possible that the neocortex in lowly brains may have a certain degree of what has been called "equipotency," that one cortical area may act as a substitute for another area artificially removed. But the more humanoid the neocortex becomes, the more the possibilities of any such equipotency disappear until finally in man the clinician and especially the surgeon have learned to have the highest respect for the exact localization of function in the cortex.

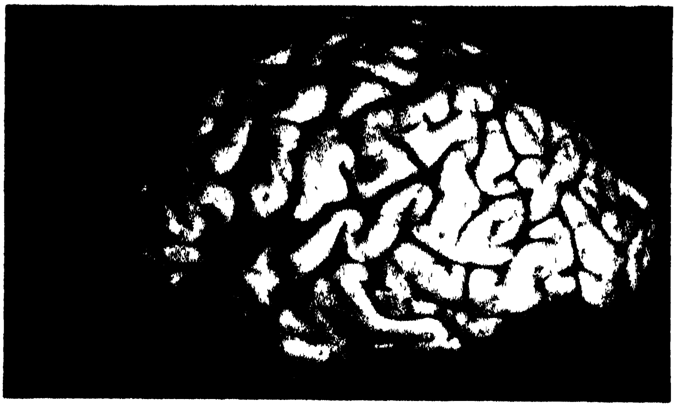


FIG 17 LEFT HEMISPHERE OF A SCIENTIST AND SCHOLAR BEQUEATHED TO THE WRITER FOR SPECIAL STUDY. THIS MAN, IN SPITE OF HIS SEVERAL OUTSTANDING TALENTS, WAS TONE-DEAF AND ENTIRELY LACKING IN MUSICAL APPRECIATION.

THE PYRAMIDAL AND EXTRAPYRAMIDAL SYSTEMS

Thus far attention has been focused on the outer aspects of the brain The internal structure of the organ now deserves consideration, particularly its groups of nerve cells, its cortical areas and the fibers uniting these regions or providing ultimate distribution of the nerve impulses. In some instances the general significance of these structures speaks for itself; in others the neural elements actually yield themselves to quantitative analysis

Functionally, one outstanding feature of the brain is its control of motion. Two great systems of nerve fibers participate in this activity, namely, the pyramidal system and the extrapyramidal system. The term extrapyramidal motor system is in many ways unfortunate. I am in full accord with Ariens Kapper's view that in discussing this system in all submammalian classes it is necessary to include the whole central motor organization. The pyramidal system is entirely wanting in all vertebrates below the mammals, and hence all their movements and postural changes come under extrapyramidal control. Furthermore, the receptors dominating the extrapyramidal system must also be included, and thus this system embraces the entire brain of birds, reptiles, amphibia and fish

In all mammals, including man, extrapyramidal function is more narrowly limited, either "justly or unjustly," to changes in motility and tonus associated with the activities of the corpus striatum, the corpus subthalamicum of Luys, the substantia nigra, the red nucleus and allied nuclei

But more than this, it has been shown that the motor cortex sends controlling fibers to all these important nuclear aggregations Because of this superimposed neocortical regulation, the mammalian extrapyramidal system is not in any sense the homologue of the corresponding system in birds, reptiles, amphibia and fish.

The advent of the neocortex in mammals subjected the ancient so-called extrapyramidal system to dominating influences which did not exist in submammalian classes

In fishes motility is specifically controlled through the midbrain by afferent impulses arising from the labyrinthine and lateral-line organs in conjunction with visual and body sense impulses. The pathways involved in afferent conveyance are the spino-tectal, spino-mesencephalic and optic tracts. The efferent pathways are the tecto-bulbar and tecto-spinal tracts. Endbrain influence in the production and guidance of motion is small or even doubtful.

In the more definitely water-living amphibia such as the salamander, conditions resemble those of the fish, but in frogs the lateral line nerves have disappeared, the auditory fibers have developed and the endbrain presents the most primitive part of the paleostriatum or basal ganglion (globus pallidus).

In reptiles the endbrain undergoes further expansion. Besides the paleostriatum (globus pallidus) these animals possess a neostriatum which is the primordium of the nucleus caudatus and putamen of the lenticular nucleus. Motor control is still mediated through the midbrain by way of the ansa lenticularis to the red nucleus. The neostriatum is in the afferent side of the arc and acts as a sensory correlating center

In birds the plan is still the same, with the exception of the added mesostriatum. This nucleus is, in effect, the outer limb of the globus pallidus

In mammals and man mediation of motor control is still, to some extent, by way of the midbrain This control, however, is extensively supplemented by three new pathways from the neocortex, which, heretofore, were non-existent. These pathways are· (1) the cortico-spinal, pyramidal system; (2) the cortico-striatal system and (3) the cortico-ponto-cerebellar system, so that now motor control is exercised through the neocortex by way of the pyramidal and allied systems.

Considering the difficulties and inconsistencies inherent in the terms pyramidal and extrapyramidal, it might be advantageous to utilize some other terminology, especially in the submammalian classes of vertebrates in which the pyramidal system is entirely lacking. The two major systems for the control of motor activities are sufficiently distinct, both from the structural and functional points of view, to require most exact definition One of them has great antiquity. Although it draws its motivating impulses from the entire field of sensory organization of the animal, it affords relatively limited brain mechanisms for the association and elaboration of these impulses. It operates without the more effective influences of a highly developed endbrain. As a system it is adequate for the regulation and direction of the behavior in fish, amphibians, reptiles and birds. The other motor system, present in mammals only, is of recent acquisition. It introduces a wholly new component in motor organization. Not only does it offer independent means for bringing into play the extensive and expansible influences of the neocortex, but it also subjects the older motor system to its far-reaching control. The so-called extrapyramidal motor system, because of its great age, might reasonably be called "*paleokinetic*," while the pyramidal system, by reason of its more recent and exclusively mammalian development, deserves the designation of "*neokinetic*." Distinction is thus clearly drawn between the motor characteristics of the mammals and those of all vertebrates which occupy positions below them in the phyletic scale.

STRUCTURAL CULMINATIONS IN THE BRAIN INDICATED BY COEFFICIENTS OF INTERNAL FEATURES

Numerous internal features of the brain bear witness to its evolutionary progress. In most instances these features are directly or indirectly connected with the development of neokinesis. Their values are estimated by planimetry, which makes it possible to establish comparative figures. Thus the percentage values of the pontile nuclei, the pyramid, the cerebral peduncle and inferior olivary body are shown in the tabulation of their planimetric coefficients. The first three of these structures are intimately connected with the neocortex and are particularly associated with the development of neokinesis. The fourth structure, namely, the inferior olive, is less exclusively neokinetic, although it is involved in steadying the movements of the tongue, larynx, palate and lips. Its increasing value culminating in man is in all probability associated with the production of spoken language (Table II)

Planimetric coefficients derived from representatives of the five primate horizons indicate the advancing values of internal structures connected with the neocortex The striking manner in which the value of the pyramidal system rises by graded stages from Tarsius to man points conclusively to the strides made in neokinetic development. The pontile nuclei and the cerebral peduncle reveal the progressive dominance of the neocortex in the control of behavior. The

TABLE II

PLANIMETRIC COEFFICIENTS OF THE PRIMATE BRAIN

	Man	Gorilla	Chimpanzee	Orang	Gibbon	Baboon	Macacus	Mycetes	Marmoset	Lemur	Tarsius
Pyramid .	183	161	.172	.160	138	.143	.147	.137	064	110	032
Pontile nuclei	550	480	.400	.300	.200	164	150	103	095	055	057
Cerebral peduncle	.321	187	223	110	110	190	169	.144	079	086	017
Inferior olive	226	186	174	172	155	.125	128	.120	038	060	042
Nucleus dentatus	176	152	136	.160	134	.165	155	130	077	.110	.059
Nucleus globosus	023	0095	018	015	020	023	014	032	050	032	037
Red nucleus	128	096	086	087	051	060	057	081	044	012	034
Superior cerebellar peduncle	088	047	047	064	063	044	046	036	048	033	.032
Inferior colliculus	070	111	132	131	130	155	175	182	210	223	337
Superior colliculus .	104	140	125	124	132	173	158	161	154	140	230
Nucleus of Goll	064	086	050	048	034	086	076	131	068	041	026
Nucleus of Burdach .	.100	081	073	093	068	065	086	113	043	049	029
Nucleus of Deiters	065	072	077	054	085	060	075	114	077	082	180
Nucleus of Schwalbe	075	070	080	055	092	095	087	090	060	045	062

TABLE III

ENCEPHALIC INDICES OF EVOLUTIONAL SIGNIFICANCE

Animal	Volume index			Weight index		
	Forebrain Per cent	Midbrain Per cent	Hindbrain Per cent	Forebrain Per cent	Midbrain Per cent	Hindbrain Per cent
Index 82 and above			Hands Fingers Finger nails			
Homo sapiens, modern man	88		11	87		12
Troglodytes gorilla, gorilla .	84		14	84		14
Simia satyrus, orang-outang	83		12	83		12
Macacus rhesus, Indian monkey	83		15	84		14
Hylobates hoolock, gibbon	82		16	82		16
Callithrix jacchus, marmoset	83		15	83		15
Index 70 to 80			Paws Hoofs Claws			
Canis familiaris, dog	80	7	13	80	5	15
Felis domestica, cat	77	6	17	75	4	21
Equus caballus, horse	80	2	18	80	2	18
Bos taurus, cattle	80	2	18	80	2	18
Camelus bachtr., camel	79	2	19	79	2	19
Elephas indicus, elephant ...	72	2	26	71	2	27
Myrmecophaga jub., giant ant-eater	75	6	19	73	5	22
Bradypus tridact., three-toed sloth .	70	10	20	70	10	20
Index . 20 to 60			Wings Fins Paddles			
Rhea americana, ostrich	58	16	26	60	13	27
Aspidonectes ferox, soft-shelled turtle	57	15	28	53	20	27
Rana sylvatica, frog		..	..	21	37	42
Gadus morrhua, cod-fish	20	40	40	20	40	40
Squalus acanthias, dog-fish	..	.	..	23	27	50

rise of this superlative tissue of the body is also reflected in the waning prominence of the superior colliculus, the homologue of the optic lobe in lower vertebrates Whereas the center of vision in birds, reptiles, amphibia and fish occupies this conspicuous lobe of the midbrain, by transference to the endbrain, it eventually finds more ample accommodation in the neocortex of the occipital region of the hemisphere

Indices and Coefficients of External Cerebral Features

The relations of the forebrain, midbrain and hindbrain by weight and volume furnish an excellent idea of the advances made by vertebrates in the acquisition and development of neokinetic control over motor activities (Table III). Animals whose indices range from 20 to 60 per cent. possess no neocortex. Their motor control consequently lacks any pyramidal elements, and such animals meet the issues of life largely by wings, fins or paddle. In cases where the range is from 70 to 80 per cent. some degree of neocortex has developed and the pyramidal system has become operative. These animals make their way by paws, hoofs and claws. In the primates the indices run from 82 to 88 per cent., climaxing in man at the highest figure and indicating the extent to which neokinesis has been developed. These indices confined to the primates indicate the increases in the forebrain and their high value in man (Table IV).

More significant still are the comparative planimetric coefficients of surface areas of the neocortex from lower mammals through the anthropoids to man. The true meaning of this comparison is the relation of the frontal lobe to the other three lobes, T.P.O. (temporal-parietal-occipital) Beginning with a low mammal, the ant-eater, which has a coefficient of 9, and gradually ascending, the coefficient of 47 for the frontal lobe is eventually reached in man

TABLE IV
Encephalic Indices

Animal	Encephalic index (per cent)		
	Forebrain	Midbrain	Hindbrain
Lemur	81	5	14
Marmoset	80.5	0.5	19
Mycetes	81.6	4.8	13.6
Baboon	83	3	14
Macacus	84	2	14
Gibbon	81	3	16
Orang-Outang	83	5	12
Chimpanzee	83	5	12
Gorilla	84	1	14
Human	86–89	1	10–13

Cerebral Evidence Derived from the Extinct Races of Man

The brain had passed through certain preliminary stages long before man made his appearance on the scene Its basic patterns had been perfected. Its most important mechanisms had been improved. In those preparatory days, all manner of animals inhabited the earth—fish, amphibians, reptiles, birds and mammals. They were the stepping stones of progress When at length the first members of our family arrived, their brains were barely human and they themselves were most crude human beings. There was a certain triumph in their advent, however, for at last there were men. They were to inaugurate a new age which was to be called the Age of Man, and was to differ from all preceding ages by the steadily increasing products of human achievement But the brain of these men was relatively small in its capacity and still unrefined in many of its structural details. Hundreds of thousands of years were necessary for such a brain as this to attain its highest efficiency. To most of us who are accustomed to reckon time as the hours between breakfast and dinner or at most as the proverbial three score years and ten, these long periods sound fabulous and fantastic. In contemplating the past our vision usually stops short at the beginning of history, five to six thousand years ago. Such a focus is unfortunately near-sighted. It leaves us insensitive to the much longer prehistoric period. Yet through all this unrecorded time, man struggled upward to achieve those successes which at length established the Age of the Frontal Lobe Much evidence of this vast prehistoric period is now available. It tells us of at least four extinct races of man Carefully examined, it reveals what the early members of our family must have been when the long human journey first started.

In all his races, living and extinct, man constitutes the sixth family in the primate suborder, *Anthropoides* (manlike) This family is known as the *Hominidae* (men of all types). The progenitors of the human family split off from a common anthropoid stock at some time in the Tertiary (Age of Mammals) At this critical juncture, variously estimated between 10,000,000 and 25,000,000 years ago, two great branches of the suborder parted company (Fig 18) Thenceforth they developed independently of each other. The first branch from this common stem gave rise to human races. From the second branch arose the great modern anthropoid apes, including the orang outang, the chimpanzee and the gorilla.

THE JAVA APE-MAN—PITHECANTHROPUS ERECTUS

Probably the oldest, most primitive of extinct races is the ape-man of Java who, although definitely human, had many simian qualities He possessed a head and face not unlike those of an ape, but his brain was nearly twice the size of any simian (940 cc). It was this great advantage which assured him an unassailable place as a member of the human family. The fossil remains of the apeman were discovered in 1891 by a Dutch army surgeon, Dr. Eugen DuBois, who made the discovery on the Bengawan River in Central Java, where he found almost the entire skullcap of this primitive man. It is estimated that Pithecanthropus lived somewhere between 500,000 and 1,000,000 years ago (Fig. 19-A).

The striking feature about the brain of the ape-man is the great expansion which has taken place in the frontal lobe Of even greater significance are the indications of a convolution in the lower portion of the frontal lobe on the left side In all living men this convolution is associated with the control of spoken language It seems probable therefore that the ape-man had acquired the powers of speech. This acquisition had a decisive bearing on the destiny of humanity

If it were possible to catalogue the chief developmental changes which determined human emergence from lower levels of animal life they doubtless would appear in the following order·

(1) The development of the human foot upon which to establish the erect posture

(2) The freeing of the hand in consequence of the erect postuie for the purposes of human progress and success

(3) The expansion of sight and hearing for better appreciation of the world and the most effective guidance of action.

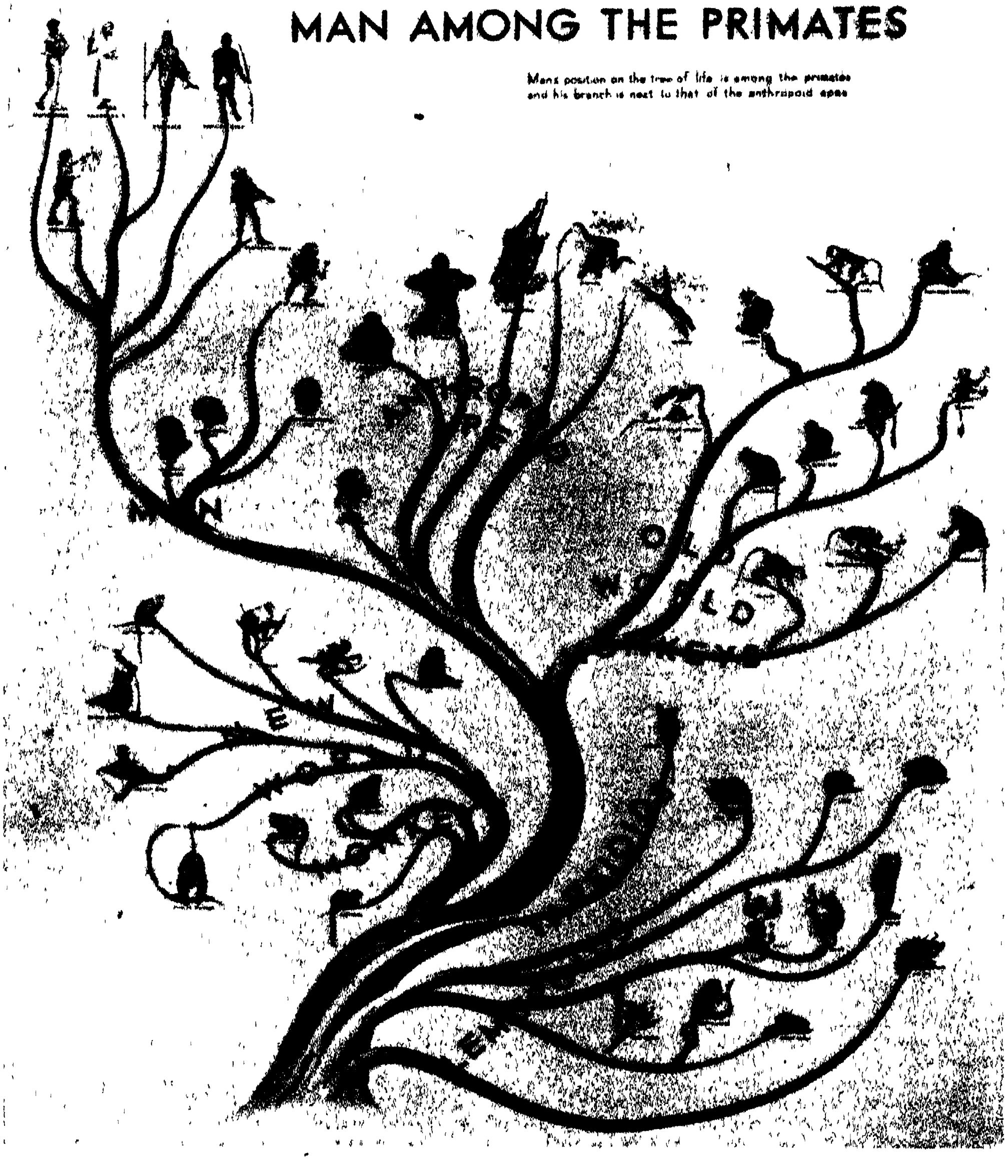
(4) The development of speech.

(5) The establishment of human personality and the development of higher mental faculties.

All these changes were directly dependent upon the growth and higher specialization of the neocortex, particularly in the region of the frontal lobe. Most of these advancements were, to some degree, operative in the ape-man of Java.

THE DAWN-MAN OF PILTDOWN, ENGLAND —EOANTHROPUS DAWSONI

From certain flints, with many features indicating their use as instruments, it is held probable that there were primitive men living in England at a time earlier than that assigned to the ape-man of Java Disputes about these early prehistoric Englishmen arise from the fact that no actual human remains of them have yet been found. This, fortunately, is not the case with the famous English dawn-man. This human fossil was found not many miles from the English Channel. The fossilized remnants consisted of a number of fragments of this extinct


MAN AMONG THE PRIMATES
Mans position on the tree of life is among the primates and his branch is next to that of the anthropoid apes

Through the courtesy of the American Museum of Natural History Drawing by Mr. E S. Lewis.

FIG. 18. THE PRIMATE BRANCH OF THE VERTEBRATE FAMILY TREE AS PREPARED BY PROFESSOR GREGORY.

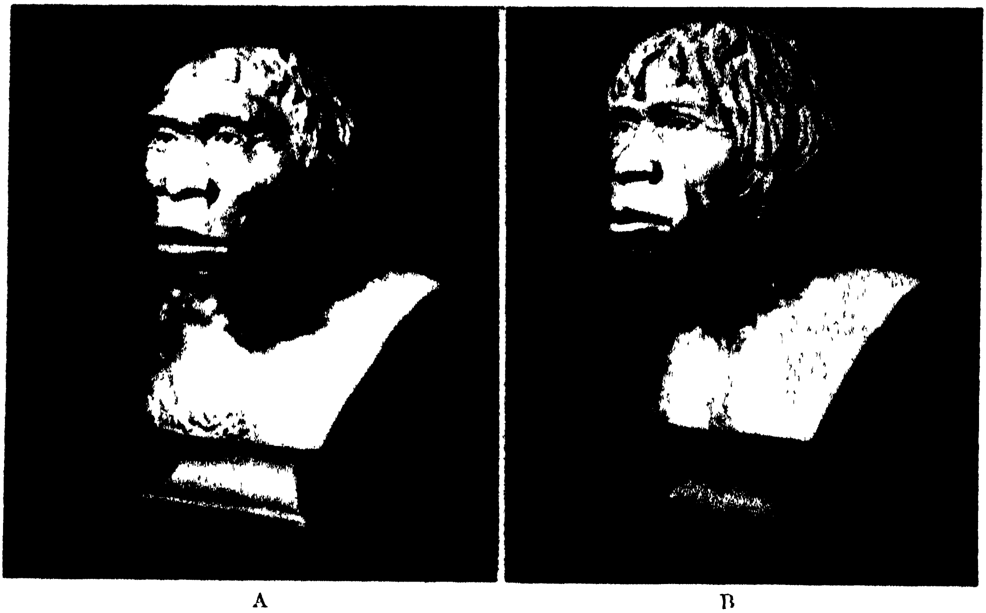


FIG. 19. MODELS OF PREHISTORIC MEN
RECONSTRUCTED BY PROFESSOR J. H. MCGREGOR OF COLUMBIA UNIVERSITY AND REPRODUCED THROUGH HIS COURTESY A, JAVA APE MAN. B, PILTDOWN MAN

man's skull. In December, 1912, Sir A Smith-Woodward and Mr Dawson presented to the Geological Society of London a reconstruction of the Piltdown skull. The announcement of this remarkable discovery made a deep stir in scientific circles. An unknown phase of early human existence was about to be revealed. The reconstructed skull impressed all who saw it as a strange blend of ape and man (Fig. 19-B). Some suggested that it was a missing link, for which the early followers of Darwin had earnestly sought. But whether this was the missing link or not, the Piltdown strata in Sussex told of a race of human beings who inhabited England long before history had made its feeblest beginnings. Dr. Smith-Woodward believes the fossil dated back to the early part of the Pleistocene period. Sir Arthur Keith and Professor Osborn give it far greater antiquity and assign it to some part of the Pliocene. Whatever the exact prehistoric era of the Piltdown fossil may be, it is clear that a primitive race of men lived in England thousands of years before Caesar's invasions, in fact ages before the ancient Celts or Goedelic Britons occupied the land. The Piltdown man is regarded by some as the direct ancestor of modern races; by others he is held to be an independent branch of the human family of quite unknown affiliations.

Several different brain-casts have been made from the reconstructed skull of the dawn-man of England. Such differences as exist in them do not contradict the fact that this brain was undeniably human and superior to that of the ape-man of Java.

Neanderthal Man—Homo Primogenius

Man's first great epoch came in the Old Stone-Age (Paleolithic, which began 900,000 years ago). A new and sturdy race of men gained the upper hand in Europe. This race is known as the Neanderthals The ancestry of these remarkable people is traced back to the Heidelberg man (Paleoanthropus) who appeared about 800,000 years ago and is considered the first man of the Old Stone Age. The Neanderthals have a probable antiquity of 600,000 years. They were hunters and the first cave-dwellers. As flint workers they made and improved many implements. Their long period of human supremacy is characterized by definite culture periods, such as the Chellean, Acheulean and Mousterian periods (Fig 20).

The scattered fossils of this famous race which have been found in many different parts of Europe all tell the story of an unusually powerful people Their arms were long and muscular, their necks thick, their legs short and slightly bent at the knees. The Neanderthal had a low retreating forehead with heavy ridges of bone arching above the eyes. The jaws were heavy, the nose broad and flat, the chin receding. All these features must have given the Neanderthal man a brutish appearance. His brain, however, attests that far from being a lowly ape-like creature he had many of the higher human attributes

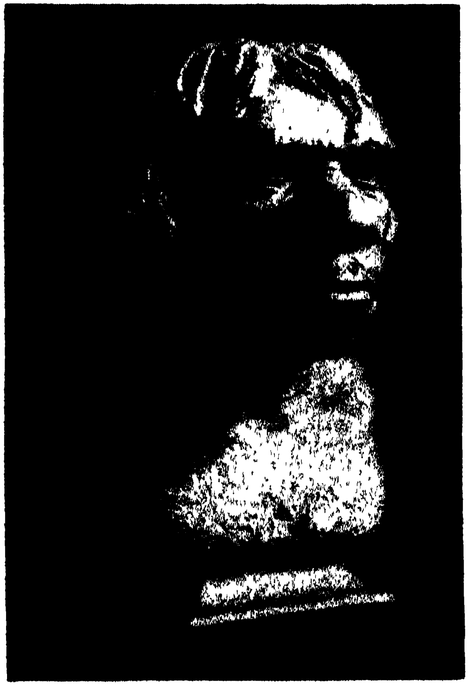


FIG. 20. MODEL OF NEANDERTHAL MAN RECONSTRUCTED ON THE SKULL FROM CHAPELLE-AUX SAINTS BY PROFESSOR J. H. MCGREGOR OF COLUMBIA UNIVERSITY AND REPRODUCED THROUGH HIS COURTESY.

The earliest discovery of these ancient people was made in 1848, when Lieutenant Flint found a Neanderthal skull in an old quarry at Gibraltar. These aggressive and productive people dominated Europe until well on toward the end of the Old Stone Age. The problem of their disappearance before the advance of a superior people has not yet been solved. The real secret in the failure of the old Neanderthal race and the success of the newcomers is doubtless to be found in the brain. It was the increased brain power of the Cromagnons which produced the supremacy of this last great race in the Old Stone Age. It was this power which gave Europe its first pioneers in art and which, for all mankind, opened the doors of creative imagination and appreciation of beauty in the world.

CROMAGNON MAN—HOMO SAPIENS

The Cromagnon has a probable antiquity of 50,000 years. He has a well-developed brain and frontal lobe of thoroughly modern type. He was an effective warrior and huntsman, but above all he was an artist. He employed and greatly refined the flint implements of the Old Stone Age and passed through successive cultural periods known as the Aurignacian, Solutrean, Magdalenian and Azilian. His chief contribution to human progress was the introduction and founding of art. He was the world's first great artist (Fig. 21).

The fate of the Cromagnon race was no exception to what had gone before or what would follow many times thereafter. Race after race, nation after nation rose, became master and passed into final decline.

As the day of Cromagnon ascendancy waned a new race invaded Europe. The Old Stone Age came to its end approximately 10,000 years ago with the advent of the more vigorous Neolithic man. With the introduction of agriculture, the domestication of animals and the establishment of permanent abode, men of the New Stone Age contributed many of the essentials of modern life. These essentials included new ways of defending their claims and asserting their rights. Such new assertiveness quickly led to the more sanguinary Ages of Bronze and Iron, with their communal equipment for offense and defense. Its influences finally spread into historic times. Ultimately these more aggressive tendencies created all the armed camps which we are pleased to call civilization, ancient, medieval and modern. At the end of the New Stone Age all the direct ancestors of modern European races were established in Europe.

The dawn of history was followed by a procession of great events, which began in the early Egyptian dynasties. The development of Pharaonic culture, the regal splendors of Babylonia and Chaldea, the incomparable achievements of Greece and Rome followed in rapid succession. Each of these civilizations contributed to the development of the race. Then came the eclipse of the Dark Ages in medieval times and at length the brilliant light of the Renaissance, the illuminating influences of which have been carried forward in the accomplishments of modern times.

This is an inspiring picture of almost uninterrupted human progress. How readily it has been taken at its face value by the most gullible of living animals, *homo sapiens!* Man has been too deeply engrossed in his ancient glories and modern proficiencies to take a good look at himself. No longer than a quarter of a century ago there were reasons for the Caucasian's pride and self-assurance. Peace existed between the nations. Success filled every walk of life. Social order rested upon firm moral foundations. This was a human establishment upon which to rely. But ultimately this record of the white man brings us to a fateful midsummer afternoon in August, 1914. The race has been the victim of many such self-inflicted catastrophies. Thus far it has always managed to come back and go forward again. Where it has stood still, where it has, perhaps, even fallen behind, is the manifest lack of control over human nature.

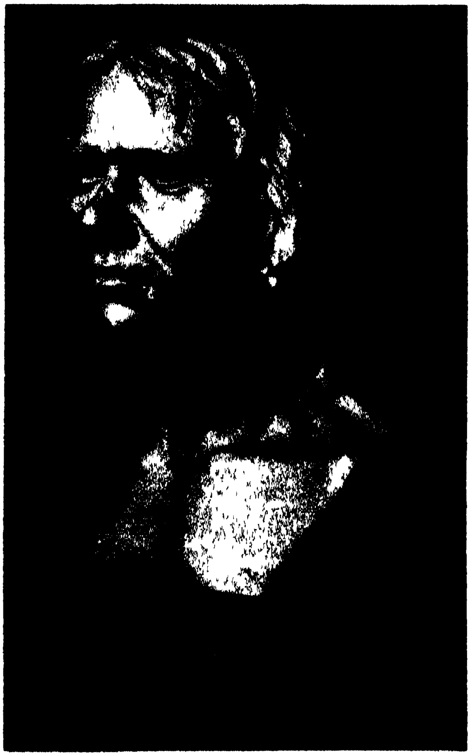


FIG. 21. MODEL OF CROMAGNON MAN
RECONSTRUCTED ON THE SKULL FROM LES EYZIES, DORDOGNE, FRANCE, BY PROFESSOR J. H. MCGREGOR OF COLUMBIA UNIVERSITY AND REPRODUCED THROUGH HIS COURTESY.

Since his early beginnings man has grown in humanity as his brain has expanded—as his forehead has risen above his eyes. Such a conclusion seems irresistible. Placed side by side, the braincasts of the ape-man of Java, the dawnman of Piltdown, the Rhodesian, the Neanderthal, the Predmost and the Modern demonstrate this steady expansion (Fig. 22). The brain area in which the greatest development has occurred is the frontal lobe. Its progressive growth since it made its first appearance gives an accurate impression of the manner in which the brain has responded to the increasing demands made upon it. There are no indications that such demands will decrease in their urgency as time goes on. This fact seems to point in a hopeful direction. It seems equally certain that upon the average only a relatively small fraction of the human brain is at present utilized to the most effective advantages in the interest of humanity. This condition would seem to mean that the power is in our own hands to bring into play more of the brain's potential energy than we have yet developed. In addition to these considerations the human cerebrum may still be looked upon as in its early youth. By most of us it is regarded as a finished product, but its long prehistoric human record as we know it to-day does not support this point of view. This long record makes it appear far more likely that the brain of modern man is only some intermediate stage in the ultimate development of the master organ of life. And furthermore, all the evidence which is available from the long subhuman history of the brain through millions of years of change and modification in the fish, amphibians, reptiles, birds and mammals conveys the strong impression that the evolutionary process has not come to an end with modern man as its culminating phase.

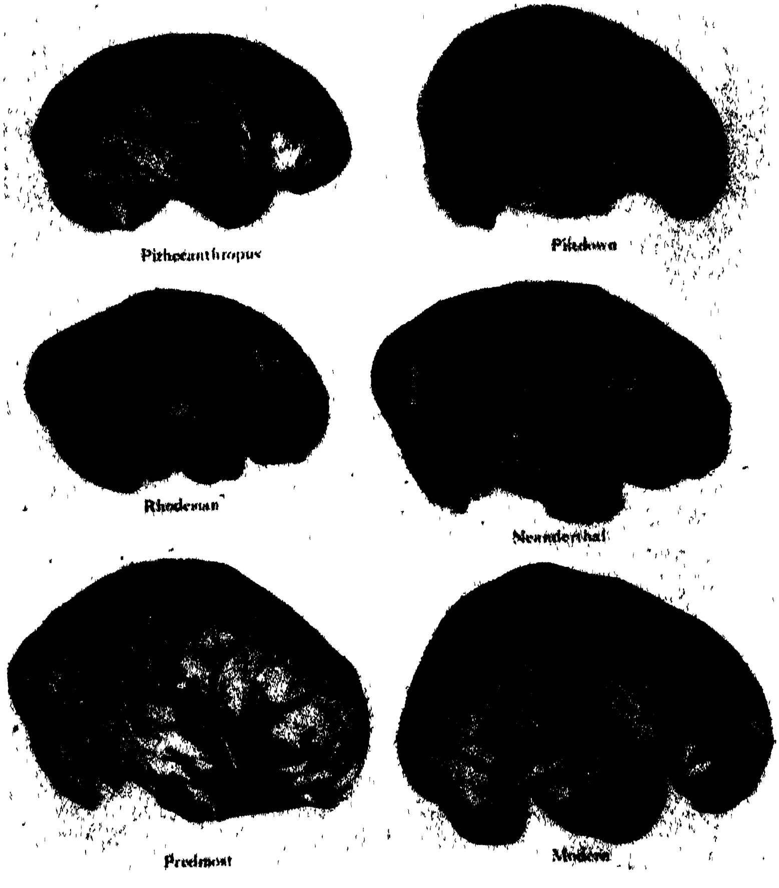


FIG. 22. COMPARISON OF BRAIN CASTS OF PREHISTORIC AND MODERN MAN.

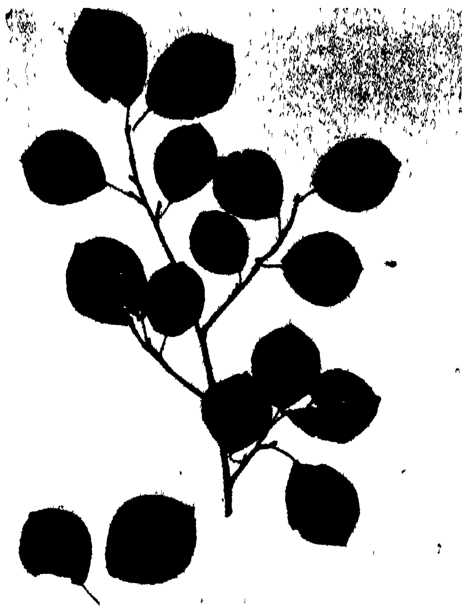
THE CAUSES OF AUTUMN COLORATION

By Professor H. F. ROBERTS
DEPARTMENT OF BOTANY, UNIVERSITY OF MANITOBA

THE annual advent of autumn brings before us a splendid pageant, the superb spectacle of the closing of the year, in which the members of the plant world wrap themselves in robes of crimson and gold, as for one last social parade, before retiring into the annual night of winter. The spectacle varies from year to year, varies in length, varies in degree of magnificence It is as though it were a somewhat human affair. Much has been written regarding the causes of autumn coloration. It was not, however, until the chemistry of the subject had been somewhat fully investigated that it was possible to deal adequately with it. In the first place, let us see just what we are concerned with.

Speaking broadly, the colors of autumn leaves fall into two groups—the reds and the yellows Without further preliminary, we may say that all the red pigmentation that appears is due to the development in the leaf of what are known as "anthocyanins." The anthocyanins are also found in other parts of the plant than the leaves, and during other seasons than autumn. Generally speaking, anthocyanins are "sun pigments," developing in the presence of sunlight. However, we have intense anthocyanin development in the roots of the beet, and in the outer tissue of the roots of the radish, which, of course, never see sunlight. In high alpine plants, there is a much greater development of anthocyanin in all parts of the plant—stems, leaves and flowers—than in plants inhabiting the lowlands, even in the case of plants of the same species. Our universally common weed, the yarrow (*Achillea millefolium*), which has white flowers in warm lowlands and southerly regions, has red flowers on lofty mountains or in the far north. Even the dandelion has darker flowers under these conditions than with us. A considerable list of plants have been subjected to experiment by European botanists, and the facts as stated have been many times confirmed. As is well known, there are many points of similarity between high alpine vegetation and Arctic vegetation It was reported by Wulff in 1902, in a special investigation of the flora of the island of Spitzbergen, that the abundant formation of anthocyanin was a distinguishing feature of the vegetation, and so much was this the case that the approach of autumnal coloration was consequently very little marked.

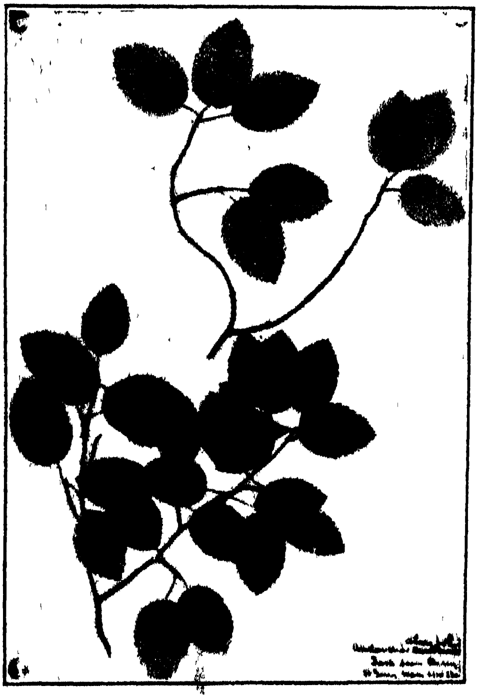
Anthocyanin develops abundantly in the floral organs of many families of plants Briefly, all red-flowered plants owe their color to the presence of an anthocyanin. It is also noticeable that in plants which bear red flowers, but of which there are also white-flowered varieties, the leaves and stems, and even the seed-coats of the red-flowered varieties, are darker than the similar parts of the white-flowered varieties, owing to the presence of the same anthocyanin which gives the color to the flowers. In sweet peas, for example, the purple- and red-flowered varieties have dark stems and leaves and bear seeds with dark seed-coats. In other words, red- and purple-flowered sweet peas bear commonly dark pigmented seeds, while light- and white-colored varieties bear light-colored seeds. As very common examples of anthocyanin in the petals, we have the ordinary red geranium, the scarlet sage, the red lobelia (*Lobelia cardinalis*), the brilliant flowers of the hyacinth and tulip, the



AMELANCHIER ALNIFOLIA NUTT, SUN-EXPOSED. DEVELOPS ANTHOCYANIN IN THE SUN: VERY LITTLE IN THE SHADE.[1]

common red hollyhocks and innumerable others. Anthocyanin may develop in leafy bracts which surround the inflorescence, as in the brilliant scarlet bracts commonly mistaken for petals, of the familiar poinsettia (*Euphorbia pulcherrima*).

Quite a number of species of trees have produced varieties with red foliage—in other words, varieties with anthocyanin development in the foliage to such an extent as to mask the green chlorophyll. We thus have the purple beech, the purple-leaved variety of the common barberry, the scarlet maple (*Acer Schwedleri*), the purple-leaved plum (*Prunus Pissardi*) and many others. In garden vegetables even, we may have anthocyanin varieties of ordinarily green-leaved species, as in the red cabbage, or in the case of the pericarp of fruits, as in certain red-fruited varieties of plums, in which the anthocyanin pigment is present in both the epicarp and mesocarp of the fleshy edible portion of the fruit. The red banana, which occasionally appears in our fruit stores, is undoubtedly simply another case of anthocyanin development in the epicarp of the fruit. Every summer and fall, we see heaps of anthocyanin fruits in the market, the blueberries, red raspberries, cranberries, high-bush cranberry (*Viburnum opulus*), in the ripe fruits of the gooseberry and many others, and in abundance in the showy but inedible fruits of one of our frequently cultivated shrubs, the Tatarian honeysuckle (*Lonicera Tatarica*) and in the fruits of the "blood orange." The color of red tomato fruits is due to quite a different pigment, lycopin, closely related to caro-



AMELANCHIER ALNIFOLIA NUTT, IN SHADE. VERY LITTLE ANTHOCYANIN.

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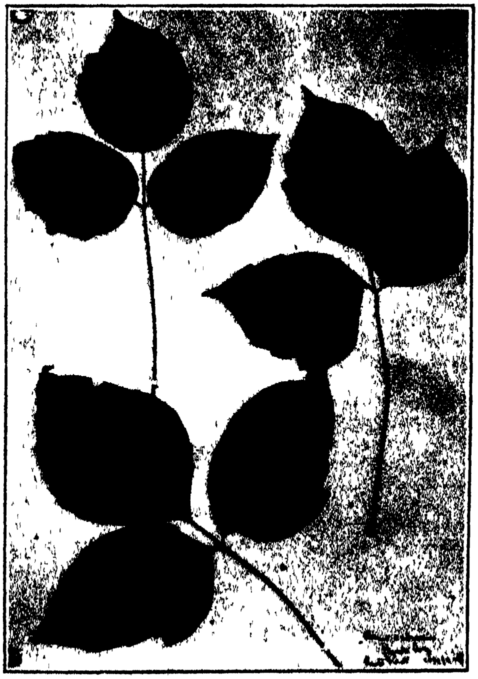
[1] The illustrations were taken on Wrattan Panchromatic plates. The color-differences come out much more clearly in the prints than it is possible to reproduce here.

tin, one of the carotinoid pigments, and not at all related to the anthocyanins.

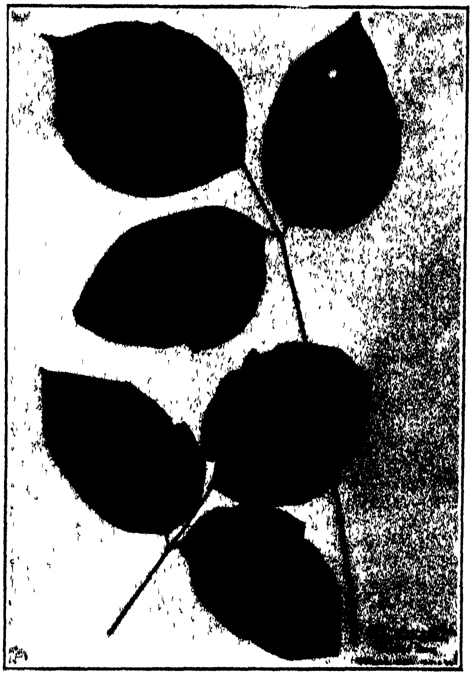
The common strawberry, in which the "fruit" is a fleshy swollen stem axis, develops an abundance of anthocyanin. It might be remarked that there are also white or non-anthocyanin forms of the strawberry. Finally, anthocyanin is sometimes developed in the testa or seed-coat of the seeds of many species of plants. This is noticeable in the case of beans, peas, sweet peas, red clover and other leguminous plants, in morning glory, in the ornamental vine *Cobaea scandens*, which has white and purple-flowered varieties, with white and dark seeds, respectively.

This will give us an idea of the wide and indeed almost universal distribution of anthocyanins in the plant world, and we have not even referred to the appearance of anthocyanin pigment in galls and wounded parts of plants, in seedlings in the cool days of early spring, in the leaves of many tropical herbs, such as begonias, or in the young leaves and shoots of tropical trees when the spring growth begins in the tropical forests, as described by Professor Keeble, of Oxford University, and others. The latter remarks that the coloration of young foliage at low latitudes "is of such general occurrence, that at the time of leaf renewal, a tropical forest rivals in its tints the autumnal forests of the temperate regions." Johow in 1884, writing of the Lesser Antilles in the West Indies, says, "All at once a red tint, due to the young foliage of the trees, appears in the landscape." The Japanese botanist, Miyoshi, in 1909, observed that leaves of trees in the East Indies, Ceylon and Java redden during the annual dry season, in a manner similar to the reddening of autumnal leaves in the temperate regions.

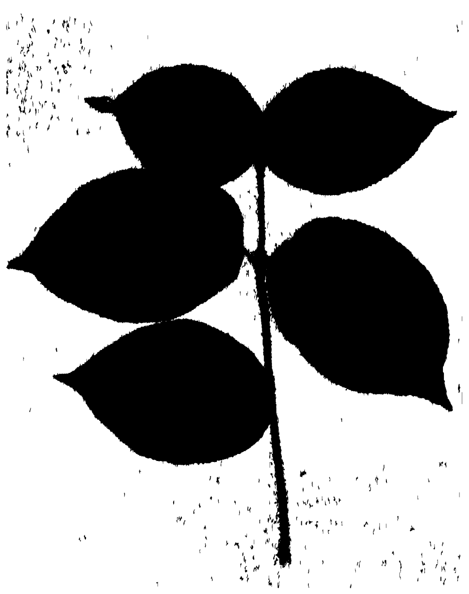
Now, what is this anthocyanin which



RHUS RADICANS (L.) KUNTZE, SUN-EXPOSED. DEEP ANTHOCYANIN COLOR.

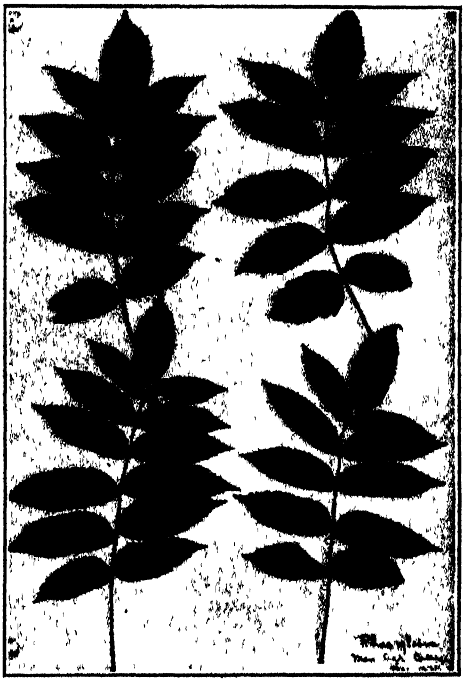


RHUS RADICANS (L.) KUNTZE, IN SHADE. VERY LITTLE ANTHOCYANIN DEVELOPED. PHOTOGRAPH UNSATISFACTORY.



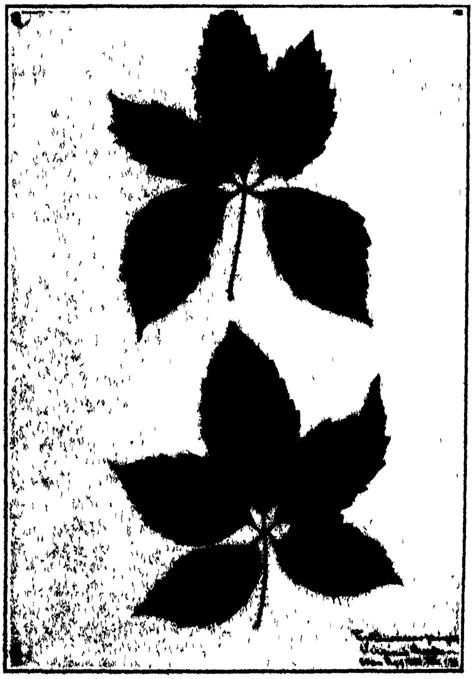
VIBURNUM LENTAGO L. ANTHOCYANIN DEEP CRIMSON ANTHOCYANIN COLOR

we find so very widely distributed in the plant kingdom? In the first place, we should say that it is what is known as a "cell sap pigment," *i.e.*, a pigment in solution in the cell sap and not found in plastids. Chlorophyll, xanthophyll, carotin and some other pigments are found in what are known as "chromatophores"—small bodies consisting of specialized masses of protoplasm of characteristic form, which act as holders of the pigment. Anthocyanin is not held in plastid bodies, but is in solution in the cell-sap If we heat a slice of beet in boiling water, and thereby kill the cells, the red pigment will diffuse from the dead cells out into the water, whereas slices of beet laid in water at ordinary temperature do not allow the anthocyanin pigment to diffuse out, but retain it in the cell sap. The anthocyanins as chemical substances are undoubtedly closely related to what are known as "glucosides." As we have seen, almost all the red, violet and blue pigments present in plants belong to the group of the anthocyanins. The chemical formula for the group may be written $C_4H_6O_6$. All or nearly all anthocyanins are red or purple in acid solution and possess green or blue shades in neutral or alkaline solution. We have said that the anthocyanins are related to the glucosides. Let us refer briefly to the glucosides. They are bodies containing carbon, hydrogen and oxygen, like other carbohydrates, sugar, for example. On treatment with acids or enzymes, a sugar, usually d-glucose, is produced The glucosides are briefly compounds of d-glucose, $C_6H_{12}O_6$, with various organic compounds. The glucosides are quite commonly found in plants The oil of bitter almonds, amygdalin, found in bitter almonds, peach and cherry pits, etc, having the chemical formula ($C_{20}H_{27}O_{11}N$), is a common glucoside. Solanin, the poisonous substance in many plants of the potato family, is a complex

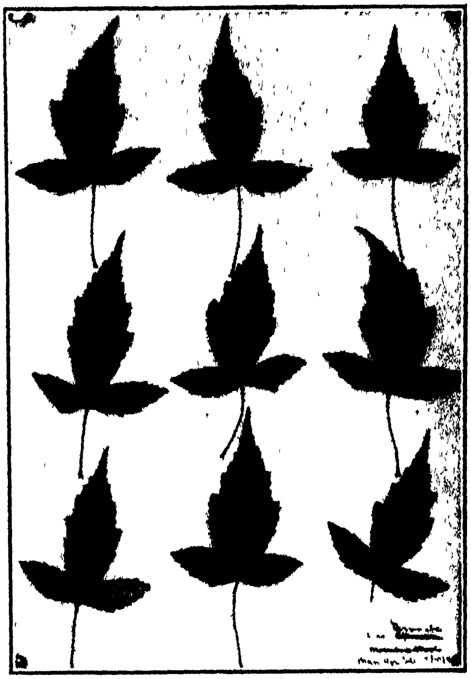


RHUS GLABRA L. ANTHOCYANIN. BRILLIANT SCARLET ANTHOCYANIN COLOR.

glucoside, $C_{54}H_{96}O_{18}N_2\ H_2O$. Salicin, $C_{13}H_{18}O_7$, is a glucoside which gives the bitter taste to willow twigs The dye indigo, originally obtained from the tropical leguminous plant *Indigofera tinctoria,* the indigo plant, is derived from a glucoside known as "indican." The drug digitalis, of great importance in medicine, is derived from four glucosides, of which the most important, digitox, is found in *Digitalis purpurea,* the foxglove, of the family Scrophulariaceae.

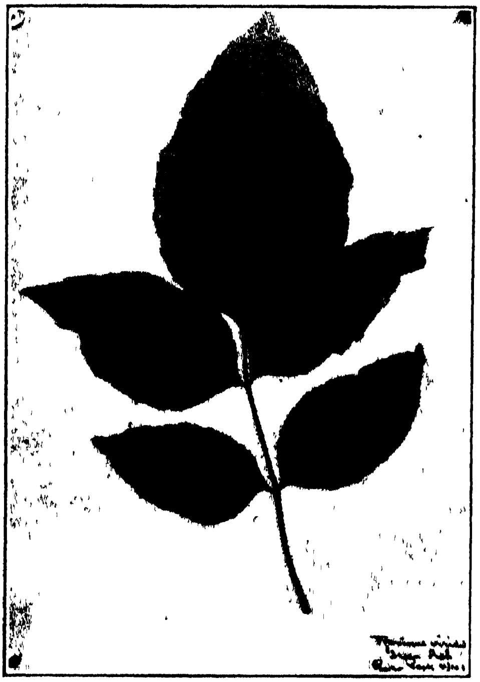


PARTHENOCISSUS QUINQUEFOLIA (L). PLANCK. ANTHOCYANIN. DEEP SCARLET ANTHOCYANIN.

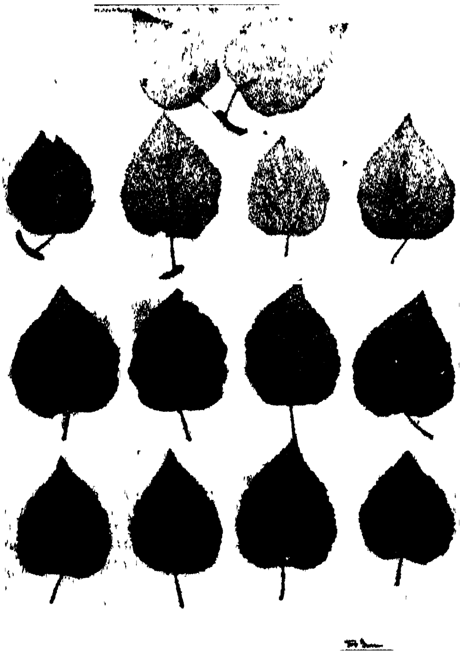


ACER GINNALA MAXIM. ANTHOCYANIN. BRILLIANT SCARLET ANTHOCYANIN.

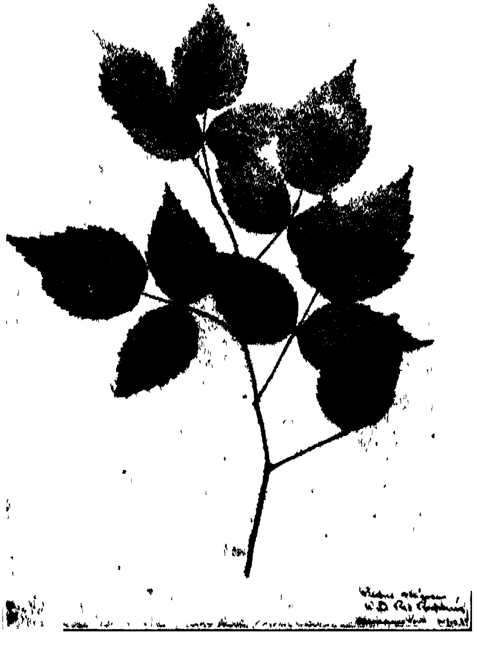
An interesting fact was discovered by Combes in 1909, that red autumn leaves of the Boston ivy, *Ampelopsis hederacea,* contain more sugars and glucosides than the green leaves of the same species, and that the amount of anthocyanin varied directly as the sugars and glucosides. Wulff found in Spitzbergen in 1902 that in arctic plants the leaves are very frequently "sugar leaves" and are commonly characterized by the presence of anthocyanin. Experiments by Ewart, on feeding sugar to water plants, show that in addition to sugar, strong light-exposure is required to cause the development of anthocyanin experimentally in these plants. Ewart's experiments were much extended by Overton in 1899, who showed that, in addition to sugar and light, low temperature is an important factor, and that, if the temperature be low but above the freezing point, the formation of the red pigment will be promoted, which accounts for the development of anthocyanin in alpine and arctic plants, and likewise for its development in autumn leaf coloration. The presence of sugar, a low temperature and strong sunlight are required to bring about the reddening of autumn leaves. It can be shown by observation that leaves of species which develop anthocyanin, if exposed to direct sunlight, fail to develop it and show only yellow pigmentation if growing in the shade. A very common instance of this is the case of the poison ivy, *Rhus radicans*. The same is true of *Viburnum opulus*, the high bush cranberry, and many other species, such as the pin cherry. It is also the case that the leaves of some species which ordinarily develop *only* the yellow pigments, such as the aspen and the Saskatoon berry, will, in intense sunlight, develop a delicate rose tint, showing the slight development of anthocyanin. That sugar is necessary for the development of anthocyanin in autumn leaves is suggested, aside from the experimental proof that has been cited, by the fact that the leaves of the native oak, *Quercus macrocarpa*, never develop anthocyanin at all on ordinary trees, even in intense sunlight. However, in water-shoots or sprouts from the stumps of felled trees, where the presence of stored organic food materials in the medullary rays and other cells of the stump and root enable a quick growth of shoots of un-



Fraxinus pennsylvanica Marsh. Non-anthocyanin. Rather poor photograph. Leaves are dark yellow.



Betula papyrifera Marsh. Non-anthocyanin. Too dark in photograph. Leaves distinctly yellow.



Rubus strigosus Michx. Non-anthocyanin. Leaves bright yellow.

usual length and unusually large leaves to develop, the development of anthocyanin in such leaves is very common and quite striking. Experiments show some variation in respect to the effect of light. Tulip, iris, hyacinth and crocus develop color normally if grown in the dark. Nasturtium and poppy develop color in the dark only if the buds are exposed just before opening. Snapdragon and other plants show less anthocyanin production in the dark, if the buds had not been previously exposed to light. Regarding fruits, it was early noticed by the French botanist, Senebier, that apples do not redden unless exposed directly to light. However, in apples, reddening is not a universal phenomenon; some varieties of apples, such as the Greening, develop no anthocyanin at all. However, in the case of fruits of which the production of anthocyanin is a characteristic feature, as in hawthorn, rose, elderberry (*Sambucus*), it was found that, with partial darkening of the fruits when green, the anthocyanin developed equally well in both the illuminated and darkened parts. Two competent investigators agree that coloration of grapes can take place in the dark.

In general, we may also say that the trees and shrubs of the temperate zone fall, loosely speaking, into classes with regard to the development of the red anthocyanin pigment. There is a tendency among the species of certain natural orders to develop anthocyanin, whereas the genera of other orders are without it. Thus the shrubs and trees of the family of the Rosaceae—species of *Pyrus* (pear), *Prunus* (plum), *Rosa* (rose), *Crataegus* (hawthorn), very readily produce anthocyanin, as do the various species of *Viburnum* of the family Caprifoliaceae. On the other hand, plants of the *Salicaceae* (willows and poplars), *Juglandaceae* (walnuts and hickories), *Betulaceae* (birches and alders), *Fagaceae* (walnut, chestnut and oak) very generally develop no anthocyanin. However, the scarlet oak (*Quercus coccinea*) and the North American hazel (*Corylus americana*) are exceptions. Grapes, hollyhocks, petunias, violets, etc., have one anthocyanin—"delphinidin chloride." Pelargonin, the least oxygenated of any of the anthocyanins, is in many scarlet flowers, such as *Salvia* (scarlet sage), purple and red asters and red geraniums. Cyanidin is the anthocyanin of deep red dahlias, cornflower and poppies, and of the fruits of cherries, cranberries, currants, mountain-ash berries, etc. Peonidin is the anthocyanin of deep red peonies.

Now we must turn from the anthocyanins, which give the autumnal reds, to the yellows of the autumn colors, and we may mention the fact that all shades of intergrading exist between autumn leaf coloration due to anthocyanins alone and coloration due to the yellow pigments alone.

The yellow pigments in the autumn leaf belong to the class of what are known as "plastid" pigments, that is, pigments borne in bodies in the cell known as "plastids." The plastid pigments of the plant cell, in the case of the higher plants, are typically four, two *green* pigments, known as chlorophyll a and chlorophyll b, and two *yellow* or *orange* pigments known as "carotinoids" called xanthophyll and carotin. These four pigments, in the case of the higher land plants, exist in the leaves, on the average, in the following proportions (in percentages of 100).

Pigment	Chemical formula	Percentage in the leaf
1. Chlorophyll a*	$C_{55}H_{72}O_5N_4Mg$.	62 per cent.
2. " b†	$C_{55}H_{70}O_6N_4Mg$.	22 " "
3. Xanthophyll	$C_{40}H_{56}O_2$	9.3
4 Carotin	$C_{40}H_{56}$	5.5

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* Chlorophyll *a* in alcohol is bluish-green with deep red fluorescence.

† Chlorophyll *b* in alcohol has a yellowish tinge as compared with a and has a brownish-red fluores-

In other words, chlorophyll a is present with chlorophyll b in the proportion of approximately 3:1. Of the two carotinoid pigments, xanthophyll is present in proportion to carotin in the ratio of nearly 2:1. In the fall, as the chlorophylls are decomposed, the carotinoid pigments become visible, often, as has already been said, together with the development of the anthocyanins. The enormous display which the two carotinoid pigments make when they do occur alone, as in the leaves of the elm, the birch and the poplars, is all the more striking when we consider the relatively small percentage by weight in the leaves, which these pigments make. Willstätter and Stoll, the great investigators of the leaf pigments, determined that the total four leaf pigments form 3.25 per cent. of the fresh weight of the leaves, and 8.21 per cent. of their dry weight. The yellow and orange pigments, taken together, form only 0.5 of *one per cent.* of the fresh weight of the leaves and only 1.9 per cent. of their dry weight. In other words, leaving out the anthocyanins, which are responsible for all the red coloration, the great sheet of yellow which spreads over our avenues of elms, and covers the ash trees in the woods, is caused by pigments which form but ½ of one per cent. of the weight of the fresh leaves. How far anthocyanin may go toward producing a color-display may be seen from the humble example of the red cabbage, in which the profound red color is caused by anthocyanin pigment found in but a *single layer of cells* beneath the epidermis of the leaves.

One more addition may possibly be furnished to the yellow pigmentation, viz., the possible occurrence of "flavones," or flavonols, compounds which usually occur in plants in the form of glucosides, *i.e.*, the flavone is combined with a sugar. The flavones themselves give rise to various dyestuffs in plants, such as quercetin, brazilin, to which the well-known haematoxylin dye derived from logwood is closely related. Haematoxylin is one of the most important of dye stuffs. It weights silk to about 200 per cent. of the original weight of the silk, and the volume of the silk is enlarged, so that the fiber has greater increase of wearing surface. However, in the plant, the compounds of flavonol and sugar known as flavone glucosides, are practically colorless. Nevertheless, by chemical action, color may develop. For instance, almost all white flowers turn yellow when exposed to the fumes of ammonia, owing to the formation of a salt of ammonium with the flavones.

The vast majority of yellow to orange-red flowers owe their color, as has been said, to the plastid bodies in the protoplasm of the cells, known as "chromatophores," containing the two carotinoid pigments, xanthophyll and carotin. Very little is known regarding the character and distribution of the carotinoids in most of these cases. In general, however, it may be said that yellows of a primrose or sulfur-yellow color are due to flavones or related pigments dissolved in the cell sap instead of being held in chromatophores. It is interesting to know that xanthophyll, for example, is also found in animal tissues, as in the yellow feathers of many brilliantly plumaged birds, such as the male canary. The color of the yolk of eggs is also due to this autumn leaf-color, xanthophyll. It appears that the autumn carotinoids never equal in quantity those present in midsummer. Tswett, in 1908, has made perhaps the most reliable study that we have at present on which to base a knowledge of the yellow autumn colors of leaves. He studied yellow autumn leaves of nineteen species, and found that the bulk of the yellow pigments before the post-mortal period of the leaf were what he called "autumn xanthophylls." He also found in autumn leaves proof of the presence of colorless substances known as "chromogens" or "color-formers," which give golden yellow salts with alkalies and which, he held, may at times play a part in autumn coloration.

The flavones, to which reference has just been made, are yellow crystalline substances with high melting-points. They either give a deep yellow or an orange-yellow coloration with alkalies. Their distribution is practically universal in plants. Almost any white flower will turn bright yellow in ammonia vapor, owing to the formation of an ammonium salt. The same yellow reaction takes place in green leaves also, but is masked by the chlorophyll. There is little doubt that the flavones are manufactured in the plants from sugar, although the actual steps are difficult to demonstrate. It has been suggested that the flavones are the sources of the anthocyanins in the plant. Combes obtained anthocyanin experimentally from red autumn leaves of the Virginia creeper, and conversely oxidized the anthocyanin and obtained a flavone.

To summarize, the yellow colors of autumn leaves are due to what are known as the "carotinoid" pigments of plants, xanthophyll and carotin, and principally to the yellow pigment xanthophyll; the red coloration is due to various glucosides known as "anthocyanins," and the varying combinations of different proportions of xanthophyll and carotin, together with the anthocyanins, give the multitude of intergrading shades of orange-yellow, red-and-yellow, red-orange, etc. We should remember that the "carotinoid" pigments are found in the chloroplasts, together with the two green chlorophylls, which give the green color to living leaves, while the anthocyanins are not found in the plastid bodies of the plant cell, but are formed in the cell sap. As the autumn draws on, the leaves become cut off from vital connection with the twigs and branches by a layer of cork, known as an "absciss layer," which forms at the base of the petiole of the leaf and which cuts off the connection between the conducting vessels of the stem and those of the leaf. This brings about gradually the death of the leaf, independently of frost. As the protoplasm of the leaf-cell dies, the plastids, which are protoplasmic bodies, die also, and the green chlorophyll held in them decomposes first, leaving the two carotinoid substances—the xanthophyll and the carotin—which had remained masked by the chlorophyll during the life of the leaf, now fully exposed, and the leaves therefore become yellow. If sugar is present and the leaves are exposed to light, an anthocyanin may be developed, and the leaves may become completely red in color. With less anthocyanin, various combinations of red and yellow develop. Thus we have the autumn pageant of glorious reds and yellows, brightening the landscape of the darkening woods, and, due to the simple fact of the death and decomposition of the green chlorophyll, which throws the hidden yellow pigments into view, supplemented by the gorgeous reds of the anthocyanins produced from the sugars of the leaf. All this occurs when the fall draws on gradually with little frost. An early hard frost destroys the yellow pigments, prevents the development of the red anthocyanins, and the leaves of the forest turn a lifeless brown.

STATE INTERVENTION IN AGRICULTURE[1]

By Dr. J. M. CAIE

Two years ago, Dr. Venn, who presided over this section during the meetings of the association at Norwich, delivered a masterly address on "The Financial and Economic Results of State Control in Agriculture." To-day my subject is "State Intervention in Agriculture," and for any apparent infringement of his copyright I tender him an apology. The reasons for my choice are twofold. In the first place, it is the custom, very rightly, for those who have the honor to be presidents of sections to deal with matters of which they have made a special study or have some first-hand experience. Being a mere administrative official and not a scientific worker, as the term is generally understood, I must, if I am to follow the excellent precedent, restrict myself to the field in which I happen to work.

My second reason is less personal. In the economic and political conditions of the world in recent years the importance of agriculture in the life of the state, not only in this country but elsewhere, has received growing recognition. That recognition may not always have been quite spontaneously accorded; rather indeed it has been extorted by economic and social forces of a most complex and compelling kind. Over-production and under-consumption, of which we have heard so much, have thrust agriculture to the middle of the stage and into the beam of a pale blue limelight. The agriculturist, cast too often for the part of the starving orphan, has raised his voice, now in lamentation, now in vituperation, calling on the state for help or fair play or protection against some industrial ogre or foreign invader. And the state, moved by his "exceeding bitter cry," has played the part sometimes of the fairy godmother, sometimes of the heavy father, and sometimes, so the farmer may say, of the deaf and cunning uncle. But never probably, save in the war years, have the state and the farmers been so closely interested in each other. And that is the second reason for my choice, which I have made in the hope that possibly a general survey of the relation of state and farmer might be of some little value. In attempting that survey, I believe that, despite the title of the paper, I shall trespass little if at all on that part of the subject which was examined so penetratingly and expounded so luminously by Dr. Venn.

One cautionary statement I must make before I go further. When speaking here, I do so entirely as a private individual and not as an official; the department to which I belong is in no way responsible for this address and must not be held as necessarily agreeing with anything it contains.

For purposes of definition, it is desirable to show, as concisely as possible, the part occupied by agriculture in the economic structure of the state. The following tables give the essential facts relating to areas, holdings and populations, the output of food from our farms, and the contribution they make to the total food consumption of the people. As a matter of interest, corresponding figures are given for two other countries, Denmark and Norway, which are more agricultural and less industrial than Great Britain. These tables have been very kindly prepared for me by Mr. W. H. Senior. Most of the data relating to Denmark have been obtained from Professor O. H. Larsen, and those for Norway from Professor Paul Borgedal; I am much indebted to these gentlemen for their kindness and courtesy.

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[1] Address of the president of the Section of Agriculture, British Association for the Advancement of Science, Nottingham, 1937.

	Great Britain	Denmark	Norway
Number of agricultural holdings.	(Over 1 acre) 455,185 (1935)	(Over 1 ha, *i e*, 2 5 acres) 204,003 (1935).	0 5 ha, *i e*, 1 25 acre) 208,550 (1930).
Total cultivated land, arable and permanent grass	29,555,271 acres (1935).	7,975,000 acres (1935) (approx).	2,500,000 acres (1930) (approx.)
Total population	44,790,485 (1930)	3,550,656 (1930)	2,814,194 (1930)
Number of people per acre of cultivated land	About 1 5	About 0 45	About 1.1
Percentage of population in agriculture	5 7 per cent (Workers of total occupied population)	29 per cent. (Workers of total occupied population)	30 per cent (All persons)

The chief facts to note here are the familiar ones, brought out in the last two lines, that in Great Britain the number of persons per acre of cultivated land, 1.5, is relatively high, being three times as many as in Denmark and nearly half as many again as in Norway, while the percentage of the population engaged in British agriculture, about 6 per cent., is very low as compared with 20 or 30 per cent. in the other two countries. Notwithstanding the importance and value of our industrial development, this figure of 6 per cent. has social and other implications which have exercised the minds of many people and need not be elaborated here.

This table shows that, as is again fairly well known, the products of our animal husbandry account for a very large proportion of the output of our land, about 72 per cent. The proportions in Denmark and Norway are even higher, and incidentally it may be remarked that in Scotland the figure stands at about 82 per cent Our milk, it will be observed, is worth much more than our beef; our eggs are more valuable than the whole of our cereal crops put together, and taken along with poultry are fully equal to our mutton and lamb This table affords much food for thought to those who are responsible for shaping the agricultural policy of the country The facts it con-

Agricultural Output, 1935

	Great Britain		Denmark		Norway	
	Pound Million	Per cent	Pound Million	Per cent	Pound Million	Per cent
Meat .						
Beef	39 0	16 2	7 4	9 1	1 7	9.1
Veal	3 1	1 3			0 7	3 4
Mutton and lamb	22 2	9 2	0 1	0 1	0 8	4 1
Pork and bacon	20 8	8 7	25 8	31 9	2 1	11 0
Sub-total	85 1	35 4	33 3	41 1	5 3	27 6
Dairy and poultry produce, etc ·						
Milk	53 9	22.4	30 2	37 3	7 7	40 3
Butter	5 1	2 1				
Cheese	2 8	1 2				
Cream	0 7	0 3				
Poultry	5 6	2.3	6 8	8 4	0 1	0 6
Eggs	17.8	7 4			1 4	7 5
Wool	1 8	0 8	—	—	—	—
Horses	0 1	0 0	1 2	1.5	—	—
Live stock and live-stock products	172 9	71.9	71 5	88.3	14 5	76 0
Crops :						
Cereal, grain and straw	13 3	5 5	5 3	6 5	1 1	5.9
Potatoes	14 9	6 2	4 2	5 2	1 1	5.5
Other crops	11.4	4 8			—	—
Fruit, vegetables, flowers and honey	27.9	11 6	—	—	2 4	12.6
Total crops, etc.	67 5	28.1	9 5	11 7	4.6	24.0
Grand total	240.4	100.0	81 0	100 0	19 1	100 0

tains and the agricultural conditions it illustrates are indeed of fundamental importance. These facts result from our soil, our climate and the consequent experience and aptitude of our farmers; they are not entirely unalterable, but any policy of improvement, development or control must primarily be based upon them.

The value of the agricultural output per acre of cultivated land is, in round figures, £8 in Great Britain and Norway, and £11 in Denmark. In contrast to this, the annual output per person in British agriculture is about £200, and in Danish about £150.

SELF-SUFFICIENCY IN REGARD TO IMPORTANT PRODUCTS

	United Kingdom 1935		Denmark 1935		Norway	
	Home Produ	Impo	Home Produ	Impo	Home Produ	Impo
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Beef and veal	53	47	100	—	100	—
Mutton and lamb	45	55	100	—	100	—
Pork and bacon	50	50	100	—	100	—
Poultry (G B)	78	22	100	—	100	—
Eggs	66	34				
Milk (liquid)	100	—	100	—	100	—
Cheese	30	70				
Butter	10	90				
Wheat	26	74	7	93	33	67
Barley	46	54	95	5		
Oats	91	9	—	—	—	—
Potatoes	96	4	100	—	100	—

N.B.—Estimates for United Kingdom and Denmark based on quantities, those for Norway on values.

The figures in this third table need little comment and are in a sense a corollary to those in the two previous tables. As regards animal products, the two Scandinavian countries are self-supporting, whereas we produce only about, very roughly, half our requirements of the various kinds of meat, nearly four fifths of our poultry and two thirds of our eggs. We produce all the liquid milk we consume, but only 30 per cent. of our cheese and 10 per cent. of our butter. Of wheat we import about three fourths of our annual ration and of barley fully half, but we grow over nine tenths of our oats and nearly all the potatoes we eat.

So much for agriculture as a producer. What about agriculture as a buyer of the products of other industries? Only a rough and possibly unreliable estimate can be given. According to the farm accounts obtained for 245 Scottish farms, of different kinds and in different districts, for the years 1934–35, the estimated expenditure on building materials, implements and machinery, electricity, fuel, chemicals, fertilizers, etc., amounted to from 14*s*. to 20*s*. per acre of cultivated land. Admittedly this is a small sample on which to base a generalization, but, taking it for what it is worth, it would represent a gross total of from twenty to thirty million pounds for the whole country. The corresponding figures per acre are for Denmark 26*s*. (based on 810 farm accounts for 1935–36), and for Norway from 12*s*. to 21*s*.

It may be noted that no allowance is made for the personal purchases of the agricultural population, which presumably would be made, more or less, no matter what the employment of the people might be. The figures represent the purchases of the agricultural industry as such and show to what extent it is the customer of other industries.

The word "intervention" is sometimes used as being equivalent to control. In this paper it has a wider meaning and is intended to cover the various ways in which the action of the state may impinge on agriculture—the "impact" of the state on agriculture, to borrow the word employed by Sir Josiah Stamp in his presidential address to the association last year. Intervention, according to this definition, falls broadly into three categories: (1) Control, *i.e.*, statutory compulsion, enforced by penalties; (2) the statutory provision of means by which agriculturists may take voluntary action to do certain things and, in the event of such action, to compel a minority to conform to the wishes of a majority; (3) the giving of direct or indirect assistance, financial, advisory, protective, etc.

Let us first consider control. A complete stranger visiting these islands might receive an impression, perhaps from an agricultural newspaper, or a farmer's meeting, that the agriculturists were oppressed by the rules and regulations of a government that joyed in tyranny, aided by a horde of official tormentors who not only battened on the sufferers but were often accused of being the real inventors of the legislative boots and thumb-screws. The depth and permanence of that impression would depend in the first place on where the stranger came from. If he came from certain European states, the impression might be fleeting; comparing conditions here with those to which he had been accustomed, he might soon say, "Here is peace: here indeed is freedom." And if he looked a little under the surface and studied the relation of state and people in this democratic country, he would discover that a government, no matter how inspired by good intentions and a large majority, could rarely if ever pass a law that was unacceptable to the general community, agricultural or other, or, if it succeeded in doing so, would find it very hard to administer it effectively. To legislate in advance of public opinion is no easy matter. Those who have to do with the formulation of legislative proposals, subsequently to be embodied in parliamentary bills, know that an Act of Parliament does not emerge suddenly, fully armed from the head of Jove. Usually it is only after prolonged discussion and consultation with organizations and individuals that a bill takes shape and gets into sufficient training, so to speak, to run the gauntlet of parliamentary criticism. It is true that a government, having to weigh as best it can the conflicting claims and interests of different industries and sections of the population, may not always meet the wishes of agriculture; but on examination it will generally be found that while it may withhold desired benefits, it seldom if ever attempts to impose an agricultural law to which there is wide and strong objection throughout the industry. The contribution of the civil servant, the so-called bureaucrat, to the legislative process may be one of labor and anxiety, but to call him the real villain of the piece is to flatter him and to ignore the fundamental and very real principle of ministerial responsibility. The British civil servant is truly a servant, informing and advising so far as he reasonably may, but always obeying loyally the government of the day, no matter what its color or its political philosophy may be. And, if I may say so, British ministers, of whatever party, do not fail to accord to the Civil Service a corresponding loyalty and that protection from any party criticism without which the service's impartiality and devotion to duty could not be maintained. The system is the product of a long evolutionary process; it may have defects, but it is at any rate the fruit of the political genius of the British nation. This, however, is something of a digression.

If our foreign visitor were historically minded, he might be interested to look into the past to see how present measures of control compare with some of those to which agriculture was subjected in former days. I have no time in this paper, nor have I the qualifications, to accompany him in any comprehensive study of the subject. One can but glance at a few of the more noticeable instances, in some cases forming precedents or foundations for later legislation. In his "English Farming Past and Present" Lord Ernle says that, "In the early stages of history, the law itself was powerless to protect individual independence or to safeguard individual rights. Agriculture, like other industries, was therefore organized on principles of graduated dependence and collective responsibility. Medieval manors in fact resembled trade guilds. . ''

These continued until the local and gradual break-up of the manorial organization of agricultural labor was accelerated by the Black Death (1348–49). Labor became so scarce that panic wages were asked and paid until in 1349 by Royal Proclamation all men and women "bond or free," unless tilling their own land or engaged in merchandise or in some other craft, were compelled to work on the land, where they lived at the rate of wages current in 1346. Here, nearly 600 years ago, was wages regulation of a pretty drastic kind, but it was a maximum that was fixed, not a minimum. Later on, in 1563, we find another notable effort to control the labor market in the Statute of Apprentices, which enacted, *inter alia,* that all persons between 12 and 60, not exempted by the statute, could be compelled to labor in husbandry and that masters unduly dismissing servants were fined and that servants unduly leaving masters were imprisoned It also stated hours of labor and provided for the fixing of wages by Justices of the Peace.

The story of land enclosure is well known and need only be mentioned as an illustration of state intervention, operating first in one direction and afterwards in another. In the sixteenth century, land enclosure, involving "the break-up of medieval agrarian partnerships and a substitution of private enterprise for the collective efforts of village associations," was opposed and partly arrested by legislation; in the eighteenth century it received from Parliament encouragement and support. Many individuals suffered, but the ultimate benefits to agricultural production and to the state as a whole can not be denied. It is interesting to note that in 1589, to relieve the laborers who lost their livelihood through the enclosure of land for pastoral purposes, it was enacted that not more than one family was to occupy each cottage, and to each cottage 4 acres of land were to be attached. The recent movement to provide allotments or small pieces of land for unemployed industrial workers seems almost like a faint echo of that distant law.

As an example of compulsion indirectly benefiting agriculture, one may cite the law passed early in the seventeenth century making it a penal offence for any person over the age of six not to wear on Sundays and holidays a cap made of English cloth. Later, in 1666, the law did not stop short even at the gates of the churchyard, for it required that the dead should be buried in shrouds of home-grown wool. In passing, it may be noted that about the same time the Government, "for the sake of multiplying seamen," had ordained fast-days on which only fish was to be eaten. With precedents of that sort before us, we are almost tempted to long for an act making the consumption of oatmeal, milk and herrings obligatory, and the possession of a tin-opener a criminal offence; it would solve several current problems of Scottish agriculture and fisheries.

Legislation of another kind prevailed throughout the eighteenth century, when home production was encouraged by the placing of a duty on the importation of foreign corn and the payment of a bounty on exported corn, combined, however, with frequent prohibitions of exports. Similar laws were enacted to encourage the raising of cattle, and importations from Ireland were prohibited. But legislation, says Lord Ernle, did not raise prices; it only succeeded in maintaining them. Increased production at home counteracted the effect which limitation of imports was designed to produce. It is unnecessary here to retell the story of the corn laws and of their repeal or to touch on more recent fiscal controversies.

The earlier instances of state intervention that I have cited were all English, but the Scottish parliament also provides us with some interesting examples. With regard to labor, the extinction of serfdom having been considered productive of indolence, a statute of 1424 required cottage holders to perform a certain amount of labor on the land, a provision for which we have had an English parallel. At almost the same date, 1426, we find Parliament taking partial control of cropping. To secure a greater variety of crop than the oats and bere which were chiefly cultivated, it was enacted that every man tilling with a plough of eight oxen should sow every year at least a firlot of wheat, half a firlot of peas and forty beans, "under the payn of ten shillings." At a much later date, 1703, a curious act relating to cultivation was passed, forbidding any butcher to have more than one acre of land for grazing unless it be tilled annually, under penalty of £100 Scots for each offence, loss of the cattle found grazing and loss of the freedom of the burgh. Public health and amenity were not overlooked, for to improve the aspect of the country, check malaria and provide shelter, all freeholders were required (1457) to plant on their land trees, hedges and broom. Nearly two hundred and fifty years later (1695) an Act for the preservation of meadow lands and pasturages near sandhills forbids the pulling up of bent, juniper and broom.

The necessity of keeping down weeds was recognized in the statute which required the cleansing of land from "guld," *i.e.*, marigold. The act, with a touch of humor now sadly lacking in modern statutes, sets forth that any one who planted "guld" deserved punishment as amply as if he had led an army against the king and barons.

Pig-feeding was discouraged. No burgess could permit swine to remain in the fields without a keeper, and they had to be kept out of plantations and hunting ground, while it was decreed by Parliament that the owner of a hog which made a hole in a meadow or open place should be compelled to fill the hole with grains of wheat.

Security of tenure is a subject of which we still hear. In the middle of the fifteenth century (1449) there was passed what might almost be called the first of the Agricultural Holdings Acts. It provided that "for the safetie and favour of the puir papil that labouris the grunde, that thay and all utheris sall remaine with their tackes unto the ischew of their terms, quhais hands that ever thay landis cum to." In other words, a change of ownership of the lands did not involve the dispossession of the sitting tenants. Our present law restricting the period for "making muirburn," *i.e.*, heather burning, goes back, with some difference of the dates, to at least 1400.

Storage of grain, a measure now advocated by some for purposes of defence, was not considered desirable in the fifteenth and sixteenth centuries, for in 1449 it was enacted that "to prevent dearth," no old stacks of corn were to be kept in the yard after Christmas; in 1452 the date was extended to the end of May; and in 1563 to the 10th of July.

These few examples of how in the past the state has laid its hand, sometimes heavily, sometimes helpfully, on agriculture are obviously very far from exhaustive and are not intended in any way to constitute a historic survey. They have been selected almost at random, to show that intervention—call it interference if you will—however much we may think we suffer from it to-day, is no new thing. You will observe that the intervention was almost all of the compulsory kind, the single exception among the instances quoted being the Scottish Act conferring a degree of security of tenure. My second category is not represented and there is no bestowal of direct benefits, such as subsidies, etc.

Having glanced at some precedents, let us consider the present state of affairs. We are all, of course, subject to state control of various kinds; we must educate our children, pay income-tax, drive our cars carefully, refrain from buying or selling certain goods after certain hours, and so on. Some people think we have far too much of such control, others find their yearnings still unsatisfied, and are eager to kiss, or to see others kissing, almost any new rod There are, indeed, probably few of us who could not mention some objectionable thing that other people ought not to be allowed to do. But here we are considering not the common burdens that have been laid upon all citizens, but only those special ones that have been imposed upon the agriculturist as such. I am not going to trouble you with a catalogue of Acts of Parliament, nor need I refer to the various compulsive or restrictive measures of war-time. It will be sufficient to mention some of the existing laws in my first category that come most readily to mind.

The farmer is bound to furnish to the government annual statistical returns of his crops and live stock. For many years the returns were made voluntarily, but since 1925 they have been compulsory. The filling up of forms is one of life's minor worries, but no one could say that the compilation of accurate agricultural statistics is not essential for the proper understanding of many of the major agricultural questions with which the government and the farmers themselves have to deal.

The Contagious Diseases of Animals Acts, administered for the whole of Great Britain by the Ministry of Agriculture and Fisheries, may at times interfere seriously with the activities of the farmer as a stock-owner, but without them he would undoubtedly be exposed to vastly greater and possibly catastrophic losses. Similarly, the Destructive Insects and Pests Acts may occasionally hamper him as a crop grower, but on the other hand they afford him protection with which he would not willingly dispense. These two laws are in fact more protective than restrictive, and I have never heard any one suggest that they should be repealed.

As a breeder of horses and cattle, the farmer must conform to the requirements of the Horse Breeding Act and the Licensing of Bulls Act, which are designed to prevent the use of inferior sires. Here again agricultural opinion is, in general, entirely on the side of the law; representations have, in fact, been received from responsible quarters that the principle should be extended to pig-breeding.

A statutory system of prescribing and enforcing the payment of minimum wages to agricultural workers has been operative in England since 1924, and Parliament has recently passed an act introducing a similar system into Scotland, where at the time of the passing of the English act, and for several years after, the workers themselves, as well as the farmers, were opposed to having such legislation. Here perhaps we come to a subject not quite free from controversy. But if it be accepted that without such legislation there is a danger that the pay of the worker might fall below the amount necessary to maintain him and his family in a reasonable degree of comfort, there are few who would deny its justice. Criticism of the law has been based not, I think, on this ground, but rather on the ground that certain other steps should be taken to enable the farmer, in his economic difficulties of recent years, to pay a satisfactory wage. The criticism, so to speak, has been consequential rather than direct; there has been little opposition to the fundamental principle embodied in the acts.

The Corn Production Act is remembered with mingled feelings. One solitary vestige of it remains in operation, the section requiring the destruction of certain specified weeds. As these are weeds which, if unchecked, may spread far and wide, there need be little sympathy with the delinquent who permits them to grow, to the detriment of his fellow-farmers.

Under the Milk and Dairies Acts, the dairy farmer, in the interests of public health, has to conform to certain standards of cleanliness, accommodation, equipment, etc.

Certain restrictions, not very onerous, are laid on farmers by such acts as the Animal Anesthetics Act, the Dangerous Drugs Act, the law relating to Heather Burning in Scotland, the Slaughter of Animals Act, and some others which may occur to you.

Whether the state presses more or less heavily on agriculture than on other businesses, *e.g.*, shipping, mining, manufacture, shops, railways, etc., I am not in a position to estimate; but later in this paper I shall venture on the opinion that the farmer is perhaps fortunate in that the hand of the law does not hold him in a tighter grasp than it does at present.

I come now to my second category of state intervention: that in which the state does not at first hand compel or prohibit, but gives farmers the opportunity to organize themselves for certain purposes and, should the necessary majority of producers decide to avail themselves of the opportunity, empowers them to secure conformity by the minority and to impose penalties on recalcitrant or erring individuals. The Agricultural Marketing Acts are the only laws that come strictly within this definition, although the Agricultural Produce (Grading and Marking) Act is similar in that the adoption of the National Mark under it is permissive, but when it is adopted it conveys a statutory guarantee of quality, with penalties for misuse. As you know, the Marketing Acts are a recent institution in this country. Hitherto, agricultural cooperation for the marketing of agricultural products had been on an entirely voluntary basis, with the advantages and disadvantages inherent in such a system: on the one hand, complete freedom of the individual, and on the other the danger that the desires of a majority might in practice be frustrated by a minority who, for various reasons—personal gain, shortsightedness, secretiveness, love of individual independence—were unwilling to observe the rules and limitations necessary to secure successful collective action. But under the Marketing Acts, cooperation can be fortified with some very effective artillery. Fundamentally, however, the principle is still voluntary and the system democratic. Unless the required majority of the producers of a certain commodity vote in favor of the marketing scheme submitted to them at a poll, the government has no power to impose a scheme upon them. In Scotland, for example, two raspberry marketing schemes have been rejected at the poll and there the matter ended. And should a scheme be adopted and approved by Parliament, it is administered by a board elected by the registered producers themselves.

The need for improved marketing methods in this country is widely, if not universally, admitted; the economic dangers and disadvantages to the farmers of the indiscriminate sale of their goods in haphazard quantities and of irregular quality by hosts of unrelated producers have been only too apparent in the past; and the weakness of purely voluntary cooperation as a remedy has been illustrated more than once. (The comparative failure of the Scottish Milk Agency scheme may be cited as an instance.) In view of all this, the difficulties and controversies to which the Marketing Acts and their derived schemes have given rise may be a matter for some surprise, but only, I think, to those not familiar with all the facts. One fact is the strong individualism of the British farmer, begotten of tradition, experience and his whole way of life. Sometimes, in the modern world, individualism may be a handicap; but the modern world too can show us many instances in which its absence is even more to be deplored. In this country most of us still believe that, in the words of John Barbour, "Freedom is ane noble thing." We must, however, retain our sense of perspective, and it is possible to exaggerate the degree of subservience to which farmers are subjected by a scheme which a majority of them was free to accept or reject and which, when accepted, is administered by their own representatives. Another and an important fact is that the marketing schemes are of a novel and necessarily complicated kind. Experience has to be gained, experiments have to be made, the engine has to be run in, mistakes in driving, sometimes serious mistakes, are inevitable for a time. Patience and tolerance are required. It is better surely to adjust the bearings and tighten loose nuts than to throw the spanner into the works and wreck the whole machine. For even the critic must admit that the acts and the schemes are at least earnest attempts to remedy serious defects in one important side of British farming.

The subject is being treated in a separate paper this morning, and I do not propose to discuss it in any further detail. But I will conclude my reference to it by quoting the opinion of one authority who has written: "The Marketing Acts are the equipment for a great experiment in the possibility of farmers organizing their industry themselves, with due regard to the interests of the consumers. If the experiment succeeds, it may postpone indefinitely such drastic changes in the structure of agriculture as those which are taking place in Soviet Russia. If it fails, not less but more control will be inevitable." How many of you will agree with that view I do not know.

Having considered briefly the methods by which the state helps the farmer by laying restrictions on him for his good and by handing him the keys with which to open, if he will, the palace called Organized Marketing, where the enchanted princess, disguised as the British housewife, awaits him, let us now, in the third place, glance for a moment at the other ways, some of them quite direct, in which he is aided and supported. Fortunately, it has been unnecessary for me to seek out all the facts from the numerous and sometimes rather elusive official publications and records in which they are contained, for that difficult task was most ably performed two years ago by Dr. Venn, to whose address I refer you. At the levels then current, the gross total of financial assistance afforded to agriculture, including forestry, and allowing for local taxation reliefs, amounted to upwards of thirty-three and a half million pounds, from which he deducted ten and a quarter millions representing the debit caused by the action of the Wages Committees, thus bringing out a net gain of about twenty-three and a half millions. Some adjustment of these figures is required at the present date. Owing to the rise in the price of wheat, the wheat subsidy, which as you know is not a direct Treasury grant but is obtained from the consumers of flour, is at present negligible. On the other hand, the cattle subsidy now stands at five millions instead of three and a third, and sums amounting to a maximum annual total of £3,490,000 have lately been promised in respect of oats and barley, lime and basic slag, land drainage and the reduction of live-stock diseases. In his balance sheet, Dr. Venn, no doubt wisely, made no allowance for the option afforded to the farmer of being assessed for income tax on his rent instead of on his actual profits, should these prove to be the greater. What that special concession is worth, it is impossible to estimate, but with any improvement in the financial position of the industry its value progressively increases.

The items in the balance sheet, apart from the recent additions which I have mentioned, are, as you may remember, wheat, beet, meat, milk, land settlement and allotments, afforestation, local taxation reliefs and administrative and development services. This last is a comprehensive item embracing many and varied matters such as live-stock improvement, land drainage, etc., and including the subjects which are of special interest to many members of this section, education and research. For the financial year 1912–13, the state grants for these subjects amounted to £65,750 in England and Wales, and £34,889 in Scotland, a total for Great Britain of £100,639, whereas in 1936 the corresponding figures were £628,570 in England and Wales, and £136,769 in Scotland, a total of £765,339.

These are large and striking increases, but it must be remembered that for many years our standard of expenditure on these services was much lower than that in several other countries, so that if we were to attain, as we have done, fairly adequate recognition of their importance within a reasonable time, a steep financial ascent was inevitable. In view of the interest in the subject, it is tempting to ascertain whether this growing outlay has been reflected in an increased yield of agricultural products. The question, however, is not an easy one to answer, since many factors are at work, and it is difficult to ascribe an increase to any particular one. The output of live-stock products, for example, must depend very largely on the prices of imported feeding stuffs. Possibly the least fallacious measure to apply is the average yield per acre of our principal crops, though here again the problem is not simple. For instance, if the total acreage of a crop falls, the average yield per acre tends to rise, since it is from the least suitable land that the crop will be withdrawn; conversely, an extended acreage will probably mean a somewhat smaller average production. It is subject to this and other qualifications that the following table should be taken as providing any indication of the effects of our education and research. The figures are for 35 years from 1900 onward and are given as quinquennial averages, so as to smooth out to some extent annual fluctuations due to weather conditions, etc.

In Great Britain as a whole, wheat, the acreage of which has fallen since the war years, shows no significant increase, oats are up by four or five bushels and potatoes by something like half a ton, but rotation hay has made no advance in spite of a reduced acreage. The results are not

Period	Wheat	Oats	Potatoes	Rot Hay
1900–04				
Acres	1,645,774	3,094,642	509,399	2,331,575
Yield	29 83 bushels	39.24 bushels	5 65 tons	29 50 cwt.
1905–09				
Acres	1,725,616	3,061,529	572,176	2,179,882
Yield	33 28 bushels	40 56 bushels	6 20 tons	30.23 cwt.
1910–14				
Acres	1,852,994	2,964,502	585,842	2,041,321
Yield	31.28 bushels	38 50 bushels	6.29 tons	28.76 cwt.
1915–19				
Acres	2,227,592	3,428,908	650,973	1,989,169
Yield	30 56 bushels	39.18 bushels	6 19 tons	29 10 cwt.
1920–24				
Acres	1,879,088	3,107,942	666,289	2,124,750
Yield	31.94 bushels	38.30 bushels	6.18 tons	28.92 cwt
1925–29				
Acres	1,546,255	2,725,711	646,886	2,000,654
Yield	32.36 bushels	43 38 bushels	6.48 tons	28.38 cwt.
1930–34				
Acres	1,516,509	2,428,413	614,942	1,884,938
Yield	32 20 bushels	43.56 bushels	6.56 tons	28.58 cwt.

spectacular, but the economic difficulties of many farmers, in the later periods, must be kept in mind. Any variations are, however, in the right direction, and striking changes in averages for the whole country could hardly be expected. A general rise in national production is bound to be a slow movement. But there are doubtless considerable numbers of the more progressive farmers who, by availing themselves of the aid offered by the scientist, have obtained increases much in excess of any shown in the table. It has to be remembered, too, that even where yields have not increased, costs of production may have been substantially reduced.

There are some other branches of state intervention which, notwithstanding their importance, it must suffice just to mention: protection of the farmer by means of import tariffs and quotas, designed to raise or maintain the prices of his products; the Agricultural Holdings Acts, controlling the relationship of landlords and tenants; land settlement legislation, which enables new holdings to be established on land which, under certain conditions, may be compulsorily acquired for the purpose.

In the course of an hour's address it is not possible to do more than take a hasty glance at this large subject, with its many interesting ramifications, any one of which might well have a whole volume to itself. But inadequate as the survey has been, there are one or two deductions that may perhaps be drawn from it.

Comparison of an agricultural country like Denmark with an industrial country such as ours must not be carried too far. Marketing and other organization, opportunities of alternative employment, standards of living, necessarily differ in the two countries. But allowing for all this, the statistical tables quoted in the earlier part of the paper suggest that British agriculture at present falls short of producing as much home-grown food as is possible and desirable for the nutrition of the people and also of affording employment on the land to as many persons as is reasonably practicable. The need of higher nutritive standards for a number of our population and the importance, in attaining these standards, of larger supplies of certain foods, in the production and marketing of which our farmers have some natural advantages, are now generally recognized. This recognition is tending to encourage the development of certain branches of our agriculture and it is to be hoped that the process will be a progressive one. Some authorities seem to consider that the sole impetus required to accelerate the process is to increase the purchasing power of the lower-paid groups of the population. That is certainly a factor of much importance, but there may be need too for education in the principles of nutrition, not only among these groups, but among some others as well. This aspect of the matter will no doubt be kept in mind should it be thought advisable to devise schemes for securing the desired object.

When speaking of the greater employment of the people on the land, one is apt to be reminded at once, and quite properly, that, thanks to the activities of the scientist and the engineer, the output per unit of agricultural labor is steadily rising. This is a tendency that can be neither ignored nor retarded. Increased production, therefore, may not necessarily cause increased employment. But, on the other hand, it is probably true that it will be long ere, in this country, the large-scale mechanized farm, the ideal of the economist, is the general and normal agricultural unit. And, given reasonable prospects of even moderate commercial success, there are many for whom rural life holds a fascination and independence denied to the townsman and the factory worker. For agriculture, as has been said, notably by Professor W. G. S. Adams, in his paper read to this section at Aberdeen, is not only a living, but a way of life. To live in that way, they are willing to risk the financial vicissitudes of the farmer or even to undertake the arduous labors of the small-holder. Cynics may call it sentiment; it is none the less a fact. But the question is by no means entirely one of settling people in new holdings; at present it is indeed rather one of making up leeway both in land and in the people employed on it. Since before the war, two million acres have gone out of arable cultivation. The reclamation of waste lands in England, the repopulating of our Scottish glens are perhaps less immediately possible, but is it too much to hope that at least a good part of these two million acres might be recovered? Were it solely a matter of farming economics, the shrinkage of our cropping area and extension of our grasslands might perhaps be regarded with equanimity, especially if the grass were of reasonably good quality. But wider issues are involved; the effects on employment and food production can not be left out of account.

In the second place, when one compares the amount of control to which agriculture is subjected by the state and the amount of benefits, direct and indirect, which it receives, one can not fail to notice some disparity between the two. The state is paying the piper fairly substantial sums, but while it exercises a little restraint over some of his actions, its only method of calling the tune is to offer special rewards for certain specified melodies. Some people may say that the payments should be larger, or different in form or in distribution; others perhaps may think that with so much foreign music available, it does not greatly matter what our piper plays. But at any rate the fact is that the selection of the tunes is ultimately determined only by individual choice. And one can hardly help asking, somewhat anxiously, whether, if the system of payments, in their various forms, is to be continued or extended, the freedom and independence of the piper can be maintained. To drop the metaphor, if it be the policy of the state to preserve and support the farmer, at considerable cost, is he to cultivate and crop his land, to produce meat or milk or other products, as he thinks best, without any dictation as to methods, quantity or quality? I would emphasize that the question is not whether the farmer should be supported and protected, but only whether there is a possibility that, sooner or later, certain consequences may follow from that policy. It is true, as I have said earlier, that it is difficult for a government to pass and to administer an unwelcome law; but if government aid were made conditional on government control, the farmer, however distasteful he found it, might be induced to swallow the pill for the sake of the gilding.

It may be argued that the state, in return for its expenditure, whether in the form of direct payments or of artificially raised prices, is entitled to demand not only certain goods, but a certain standard of performance, a view that found expression in Part IV of the Corn Production Act, which gave "Power to enforce proper cultivation." In response to that argument, it may be claimed that if the farmer is to be bound to produce commodities of a kind, quality and amount determined according to the kind and area of his land, he should be insured against any loss incurred in the process. And that leads to the further question: if he is to be insured against loss, is he to be left free to make unlimited profits, should his efforts prove successful? It is easy to follow out this line of thought and to see complete control, including rents as well as wages, following in due course, and, indeed, the ultimate incorporation of every agriculturist in the Civil Service! *Timeo Danaos et dona ferentes!* Possibly this is all merely academic speculation, but given the premise of state support, the subsequent reasoning does not seem to be entirely fallacious. Whether the conclusion, if it were ever reached, would be a desirable one, is a matter for individual opinion.

Thirdly, it may be noted that, while some of the state benefits, *e.g.*, rating relief, the fruits of education and research, etc., are bestowed upon all, certain others, *e.g.*, the wheat and beet subsidies, are, owing to natural conditions, not universally available. This is a thorny subject—although not quite so prickly as it was a few months ago—about which some of us have heard a good deal in the last year or two. The state is, of course, entitled to pay for those commodities the production of which it wishes to maintain or increase, or to come to the rescue of those whom it deems most needful or deserving of succor. If, for instance, a "nutrition" policy required an increase of, say, meat or milk or fresh vegetables, or if the agriculture of one part of the country were, for some reason, in special jeopardy, the disbursement of funds for such purposes would appear to be perfectly legitimate. But if it were a permanent policy for the state to support British agriculture in general, it might perhaps be desirable to survey the whole industry, its place in the social and economic structure of the country, its present and potential capacity to meet the food requirements of the people and its relation to international trade. These subjects are no doubt being studied now, but it can hardly be claimed that the study is complete. Perhaps it never can be completed, for many of the factors are far from static. But if a comprehensive, reliable and possibly continuous survey could be made, it might form the basis on which state aid might be allocated equitably, from time to time, to those branches of the industry which it was desired, in the public interest, to encourage and in proportions according to their needs. But on this assumption, the shadow of state control still lurks darkly in the background.

This leads one, lastly, to consider whether in state aid, with its attendant shadow, lies the only hope for British agriculture. The question is one of paramount importance and of formidable difficulty, on which any one should hesitate to dogmatize. But for some at any rate there would be comfort in the belief, if they could hold it, that our farmers, given a fair share of our home markets, could once more struggle through their difficulties and maintain their position by their own initiative, energy and resource. For many of them, times have been hard, but many too are riding out the storm with courage and success. Observation, supported by careful economic investigation, shows that the personal factor is still one of enormous importance. Within one parish, even on neighboring farms, great disparity in farming practice and results may be found. The man of enterprise and adaptability, the man who is eager to acquire new information, to test new methods in the light of his practical experience and to apply his mind to the business management of his undertaking, he is the man who is least clamant for state subvention to help him in balancing his accounts. Education and research, both scientific and economic, have yet many gifts in store, gifts the acceptance of which carries no penalties. If they be accepted willingly and applied diligently, is it not possible that the general standard of our farming might be raised to a level at which it would be beyond the reach of any, save the very heaviest, waves of depression? If not, there seems to be at least a risk that our farming, no longer the free industry that we know and respect, may become a mere hanger-on of the state, dependent on its bounty and subject to its commands. Economic independence is worth a struggle, for with it may go a higher kind of freedom that is worth the hardest fight of which man is capable.

TALAMANCA

By RALPH E. DANFORTH
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"The Cordillera of Talamanca, the most extensive mountain chain and the one containing the loftiest peaks. This area is difficult of access and has hardly been touched by the botanist, although it is likely to prove the most remunerative part of the Republic." So wrote an eminent scientist and traveler, Dr. Paul C. Standley, in the annual report of the Smithsonian Institution of 1924

Talamanca became a charmed word to me and the difficult and little-known southeastern half of Costa Rica, containing the highest mountains in Central America, became a mecca for a future pilgrimage. It contains a vast virgin forest, as wild as that encountered by the first white settlers in America. Its trees average about one hundred and twenty feet in height, many of them one hundred and fifty and two hundred feet, with clear stems and the lower limbs eighty or ninety feet up. Mountain torrents dash down its steeps, overarched by the straining limbs, yet often too wide for these to conceal. From the air above, these broader rivers are seen to lace the vast, rugged expanse of green with lines of frosted silver and add to the strange bird songs the roar of cataracts and the song of the incessant battle between torrents and bowlders and ledges. But why leave the comforts of a New England home to do a bit of research in a region destitute of the basic comforts of civilization? Partly perhaps the blood of pioneer ancestors, partly the jungle pictures in the geography book of schooldays, the fascinating monkeys swinging on lianas, the pictures of tropical birds on strange trees of the jungle. All through life the wilderness trees and their inhabitants have lured me in many lands. Talamanca's turn came. I reached the civilized belt which stretches across the middle of Costa Rica, with its comfortable cities dotting the railroad and excellent highways. I read of its cowboy and cattle country to the northwest, but of the southeast the majority of Costa Ricans themselves know little. The few frontiersmen who live in the little clearings in the forest seldom come to town and when there are quiet and unobtrusive. The townsfolk told me they knew little of the Talamanca Mountains or what one might expect who penetrated them. They had heard of poisonous snakes, "*león*" and "*tigre,*" as they call their cougar and jaguar. They knew there were some Indians, though fewer than before. One could not enter by wheeled vehicles. One might go on foot or mountain pony, carrying blankets and food, or now he can fly by small local planes to a few of the larger clearings which depend upon these planes for all transportation which can not take many days of rough travel over narrow, mountain trails.

Flying thus southeasterly, from ten degrees north of the equator at San José to nine and a fraction degrees at San Isidro del General, I reached the base of Chirripó Grande, the highest group of peaks in the Talamancas The highest peak is 12,586 feet above sea-level. Looking down from above on range after range of mountains clad in unbroken forest, one is amazed at the vigor and vitality of the trees. Each looks so perfectly healthy, although never dusted or sprayed for insect pests. Shades of green differ with the species. Here a palm or two appear among the broad-leaved trees, or a few tree-ferns vary the foliage. What new species might abound or what rare finds were awaiting among those millions of energetic trees? The biological balance in the jungle is so perfect that despite fierce competition between living organisms the myriads of forms which fill it seem vigorous, superbly healthy and, to me, they appear peacefully happy. Large flocks of parrots flew together in a wheeling, exuberant flight, noisy and unmistakably joyous. Unless one mistook their every act and sound they were glad, sporting together in the air as they flew from one food tree to another. Whatever perils the jungle had for them, these did not dampen their spirits, and having seen the joy of living which these free and far-flying birds show almost constantly, I felt I could henceforth view captive parrots only with pity, as they live lives so diametrically opposite their life in the wild. Strangely colored toucans with huge bills sang creaking songs which carried far across country and might mislead one into thinking that ox-carts with ungreased axles abounded in the wilderness, when in truth the few carts had to be assembled or made in the clearing. Birds large and small, plain and gay, abound, more, it seemed to me, than in the West Indies. Lizards were fewer, and mosquitoes almost non-existent. Fleas bothered only in the village and might easily be avoided in a camp in the edge of the forest if dogs and people infested with them were barred. In the forest the air was of the sweetest. No pests bothered, unless one stirred up a colony of stinging ants inhabiting some hollow stem, though these were easily removed. Snakes and beasts there were, but these were as loath to meet man as any one might wish.

Dr. Alexander F. Skutch, a young American scientist, is spending many months in the region studying habits of living birds while he collects and preserves plant specimens for museums to make his living. He lives in a camp by himself, hiring two boys to assist in house and field. He lived "three hours on foot" from where I stopped, but he was many miles above his camp when I sought and found him. On the mountain-side I visited with him two hours as he worked. Rain is frequent and the plant-press must be protected as one works. In my own collecting the numerous rivers afforded chances to pick flowering specimens from trees which ordinarily hold these treasures ninety feet or so in air. The smaller trees are more easily collected. Skutch was collecting seven series of everything from ferns up. He surely earns his living, but what a rare environment to live and work in!

My own time in the actual forest was limited to three weeks. Every moment must count, so I camped on the edge of the clearing, where I suffered from fleas nightly, and bought food ready-cooked and saturated with grease, sooner than take time to establish myself in the actual woods and cook the food myself to my own taste. But I resolved hereafter to take time to do it the right way. Fortunately I endured the fleas and the grease with no permanent detriment to health, and so had every hour of daylight for study of the forest. It was August, 1936, therefore in the rainy season, and only a fraction of the species were in bloom. As I was out primarily for specimens of trees actually in flower my scope was limited. The forty odd species I did find in bloom were of great interest. They represented many genera and families and included two species new to science. *Cordia chirripensis* Standl. and *Rollinia Danforthii* Standl., also one South American species, *Wikstroemia fruticosa* Schrad., which had not previously been found in Central America, and one rarity, *Stryphnodendron excelsum* Harms., which had not been found since the type collection in June, 1903.

Everything in that vast virgin forest excited curiosity; the species not in bloom seemed almost endless; birds abounded both in number of individuals and number of species. Pests and diseases of the trees seemed under excellent natural control. Indian graves, betokening a more numerous population in the past, were being searched for gold and other valuables.

Rushing mountain rivers abounded everywhere, and it was along their courses that I was most successful in reaching flowering branches which ordinarily would be high above reach. This entailed much wading and swimming and climbing over slippery rocks. The water from higher up the mountains was always cold. Rain also drenched me nearly every afternoon. Life was strenuous but thrilling.

The present state of civilization in that unique and youthful pioneer clearing known as San Isidro del General is worthy of a few comments. There was one Romanist church with a young German padre. There was no inn or lodging room in the village. Two huts offered hot meals, such as they were, for sale. What few dwellings there were were grouped around a flat open field called hopefully the Plaza. One hut housed the post office and government radio station. The settlement was served by three competing local airplane companies. Pan American planes flew high overhead, traversing the length of Central America and Mexico, but of course made no stop at small places. There were several small stores, most of them run by Chinamen. All mail and practically all goods to or from San José were carried by airplane. When it came time for me to leave the forest I wanted to mail a number of heavy packages to West Boylston, Massachusetts, and took them to the San Isidro del General post office without really high hopes of success. But the postmaster said I could mail them to the States, but he had no tariff but would radio at once for rates. These came back from San José without delay, and he soon showed me them neatly typewritten. But alas, he had no scales for packages, so we took them to the agent of one of the aviation companies and he weighed them, for cheerful cooperation in a pioneer clearing is essential. The local post office kept no postage stamps, but took the cash, and by some system the proper stamps were put on in San José, always on the bottom of the package or back of the envelope. The business of the clearing was far larger than the few houses would warrant, for it was the center for isolated individual clearings for many miles around.

There was much excitement over the prospect of the Pan American highway passing through. They knew it would develop the region, yet feared the consequences in case of war.

Weddings occurred at 6 A.M. in the church, the ceremony being followed by a wedding breakfast in a neighboring house. I was invited to one such breakfast, which consisted of sandwiches, home-made cake and coffee. The usual meals consist of home-grown rice, black or red beans, potatoes, which are also grown in the mountains; tortillas made from corn meal, a few fruits and a few other vegetables and a little bread are used. Agua dulce is often substituted for coffee. This is crude sugar in hot water. The lumber is hand-sawn and used while still green. House wrens much like ours at home nest in the thatched roofs. The many birds of the forest always added to the pleasure of tree study.

If the big highway does go through the

region, it will hasten the ruin of that magnificent forest. Even now it is a shame to see it cut and burned to rid the ground of it, ground much of which should never be cleared. The whole Talamanca range of mountains would make a magnificent national park, which, when better known, would draw people from all around the world. Its flora and fauna are unique in many respects, and mingled with its many endemic species are also forms from South America, from Mexico, and in winter from much further north. But if the entire range would be too much to ask for, at least that Chirripó Grande massif, which towers above all the rest of the range, should become at once a permanent virgin and wild-life refuge with complete protection from fire and axe.

Scientifically managed forests for timber production should be provided over increasing areas. Wild forests, in which nature is left entirely free to conserve or to reconstruct primeval or virgin forest conditions, will always be needed in generous amounts for study purposes and for instruction and edification of the people. Such wild forests should exist in every distinctively typical forest region, and should contain as many native species and as many endemic species of tree and shrub as possible. The educational value of such wild forest consists not only in the opportunity to study the various species at all seasons in their natural habitat, but also in showing how nature deals with the infinite number of biological problems arising in various ecological and different climatic environments. There is also the esthetic value of such wild areas, appealing to an ever increasing number of people in all parts of the world, and there is the artistic side to be treasured.

Virgin forests could and should be permanently conserved in all far-away regions. They might with benefit be reconstructed, in limited amount, close to our large cities and in all more densely populated areas. They have their peculiar values, as have also our more familiar city and state parks It would do the public good to visit areas where they know there can be absolutely no tampering with nature, no destruction, no "improving" and no exploitation, only a few narrow trails to admit observers.

FROM FANCIES TO FACTS IN DIAGNOSTIC MEDICINE

By Dr. J. HEYWARD GIBBES
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ARCHEOLOGY, anthropology and the study of primitive peoples show conclusively that medicine, meaning thereby the healing art in some form or other, is as old as man—that the dawn of his consciousness brought with it a striving to recover from disease, to heal himself when injured and to diminish the pangs of pain. Surgical instruments have been found by the archeologist, in their particular human settings, from the Stone Ages through the Bronze and Iron Ages, and anthropologists have discovered human bones in these respective ages which show that primitive man knew how to reduce and fix fractures so as to prevent shortening and to permit of union Primitive peoples of to-day, some of whom are living under conditions of Stone Age Man, such as the Dayaks of Borneo, some of the Malay tribes, and others, together with what we know of the medical customs of the American Indian, have allowed us to see in actual operation the thought and practice of early man in his efforts to get relief when sick. B. M. Randolph has said that there is "a deep-lying instinct in human nature that relief from suffering is an obtainable goal," and the history of man's striving to satisfy this instinct is the history of medicine.

The sensation of pain, the capacity to suffer and the desire for relief naturally made themselves felt in man before his mental processes, based on experience and observation, had become sufficiently organized to permit of an understanding by him of the causes that produced his misfortunes. In the beginning he probably suffered and vaguely hoped for some surcease. Aches and pains, chills and fever, stiffness of joints, shortness of breath, the pangs of angina, the fits of epilepsy, the gnawing of ulcers, the depressions and excitements of mental aberrations and innumerable other agonies seized him or crept upon him without his knowing how or why. But as he suffered he thought, groping for explanations of the evils that beset him, seeking for intelligent direction in deliverance from them, and instinctively knowing that he must find the causes of his troubles if he were to cure them or avoid them in the future. Out of this thinking came his theories of disease, working hypotheses of cause and effect, that would serve as a foundation on which to build measures for restoration of health in mind and body.

Specialized thinking on such subjects was assumed at an early date by the recognized mental leaders of the tribe, the priests, the chiefs or others who, through special qualifications, were set apart from the rank and file. And thus we have the groundwork for the study of medicine, the observation of disease, the ceaseless theorizing about it, and the endless effort to explain it, understand it and relieve it.

What we have come to call theory and practice have gone hand in hand, and when the one has been empirical and unintelligent, the other has taken on like qualities. Theory, in medicine, has come to mean knowledge: where it is short of this, practice must remain uncertain and insecure. It is my purpose to rapidly trace the steps by which medicine, in its diagnostic aspects, has progressed from primitive conceptions to its present stage of relative mechanical accuracy.

Early man was surrounded with mystery. He explained himself and the world about him in terms of mystery. He found his destiny moulded by gods and devils, demons and spirits. His diseases came from devils and demons—his cures came from driving out the malignant influences that pervaded him. To meet such problems, his medicine men dressed in weird costumes, dealt in charms and incantations, danced mystic dances and performed esoteric rites for his relief.

A tangible evidence of the demonology of primitive medicine is found in neolithic skulls, recovered from many parts of the world, that show numerous trephine openings, small disks of bone having been removed so that the demons causing the disease might escape. This interpretation is warranted by observations of similar practices by barbarous peoples of our time.

Our knowledge of Egyptian medicine comes largely from six or seven papyri dealing specifically with this subject. The Ebers papyrus, dating from about 1500 B.C., indicates a persistence of demonology as a cause of disease, with incantations as measures of relief, but gives a remarkable list of pharmaceuticals, ointments, inhalations, enemeta, poultices, drugs, such as opium, castor oil and squills, and shows that more or less skilled operations on the eye were undertaken. While we are struck with some of the empirical successes of this period, we realize that mystery and magic remained the foundation of the thought of Egyptian medicine, and that they were groping without understanding.

Astrology and divination were the bases of the theory and practice of medicine in Babylonia and Assyria. The reading of horoscopes in the heavens and the divination of destinies as disclosed by inspection of the organs of animals, especially the liver, indicated the mystic formula that was to be used in exorcising the demon from the afflicted person. Hepatoscopy, the reading of the liver, was developed into a complicated rite, elaborate charts of the liver were prepared, and an accurate reading of the signs disclosed by the organ were confidently expected to give useful information as to the cause and cure of disease.

It remained for the Greeks to banish demons from the realm of medicine, not by making holes in the skull, but by enlightening the mind from within by inquisitive thinking and by "lifting the veil of nature," as Dr. Osler has expressed it, so that we might observe and study her features. Among the factors that led to the development of the vigor of the Greek intellect, Gomperz says, "there was the religion of Hellas, which afforded complete satisfaction to the requirements of sentiment, and yet left the intelligence free to perform its destructive work." The Greek intelligence quickly destroyed the demons of disease. Under the Greek influence, medicine, along with the study of nature in general, gradually became emancipated from the shackles which had bound it to the religious thought and customs of all preceding peoples.

Abstract thinking and speculative inquiry, guided by the principles of logic, were the chief weapons employed by the Greeks in their study of nature and in their development of science, and, until observation and inductive methods were developed, they elaborated theories of humors and numbers in their relation to disease that appear to us weird and fanciful. Some of them, however, spurred by a restless curiosity, resorted to dissection, made accurate and enduring observations, and laid the foundation of a knowledge of anatomy, from which root spring all the branches of medical science. Notable among these were Alcmaeon, a member of the Crotonian school, who first recognized the brain as the organ of mind, Democritus, who developed an atomic theory, and Diogenes. Hippocrates codified, as it were, the medical concepts of the period, showed the value of painstaking clinical observations, and voiced many sapient aphorisms that we like to repeat to this day. He it was that said, "experience is fallacious and judgement difficult," and "the remedy amuses the patient while Nature cures the disease." The greatest observer and systematizer of them all was Aristotle, who came close, indeed, to an unravelling of many of nature's secrets. As regards medicine he says:

> But health and disease also claim the attention of the scientist, and not merely of the physician, in so far as an account of their causes is concerned. The extent to which these two differ and investigate diverse provinces must not escape us, since facts show that their inquiries are, at least to a certain extent conterminus. For physicians of culture and refinement make some mention of natural science, and claim to derive their principles from it, while the most accomplished investigators into nature generally push their studies so far as to conclude with an account of medical principles.

The philosophical vigor of the Greeks must forever remain a source of unending charm and inspiration to any one whose soul has beauty in it and whose mind is spurred by curiosity, even though they have served to show us that abstract thought and simple observation will not wring nature's answers from her—that questions must be asked through orderly and controlled experiments, a method that must be added to theirs from the full fruition of an inquiring intelligence.

It is not until we reach the Renaissance that we find the newly awakened intelligence of man, rediscovering the wisdom of the Greeks and adding a new *modus operandi* to his way of thinking, effectively investigating natural phenomena, acquiring information hitherto unknown and slowly laying by in enduring form a mass of knowledge to be built on and added to as his experience grew and his methods of investigation improved. As Aristotle suggested, the growth of natural science caused medicine to grow with it, and medicine rapidly developed a science of its own.

It is axiomatic that anatomy is the foundation of intelligent medicine. The structure of the body as a whole, and of its parts and organs separately, must be known in detail before the diseases and disorders to which they are subject can be comprehended. As we look back over the vista of human knowledge, we see outstanding in the realm of anatomy the colossal figure of one man, Andreas Vesalius (1514–1564), who, through genius, industry and daring, exposed the fallacies of the past and established truths for the future. Anatomical knowledge of a sort had preceded him, sporadic observations here and there concerning the structure of the human body, mixed with information gained from dissection of the lower animals, and the whole joined together in a maze of theories, doctrines and generalizations that were fixed and unchanging under the dominance of authoritarianism. Galen had written the medical bible, his word was the law, and to question it was to be guilty of medical heresy. As Vesalius dissected his human subjects, he read his Galen, and he was amazed to find the discrepancies between the texts and the facts. It grips the imagination to picture the conflict that arose within him, the growing feeling that truth and authority were at odds. And, then, the light—the realization that Galen had not dissected the body of man, but had described the anatomy of lower animals. This brought comfort to the mind of Vesalius, and stimulated him to his task, though it did not lighten his difficulties in persuading others that Galen had been wrong. In 1543, at the age of twenty-eight, Vesalius published his book, "De humani fabrica," containing 663 pages in folio and over 300 illustrations, the first complete text-book of human anatomy. From this substantial beginning the knowledge of gross anatomy has been completed to infinite detail.

In the same year that Vesalius died, 1564, Galileo was born, destined to discover the compound microscope, through which agency gross anatomy was to be supplemented and rendered complete by microscopic anatomy of organs and tissues. Antony van Leeuwenhoeck (1632–1723) was a pioneer in this field. Grinding his own lenses and making his own microscopes, he visualized bacteria, observed the cross striation in muscle fibers and described the bone corpuscles. But Marcello Malpighi (1628–1694) was the first to systematically study microscopic anatomy. He was to this branch of knowledge what Vesalius had been to gross anatomy. The two of them pointed the way that has led to a rounded knowledge of the detailed structure of the human body.

To pragmatic medicine a knowledge of function is of equal importance with that of structure. On these two pillars, anatomy and physiology, rests the intelligent foundation of medicine as we know it to-day. William Harvey (1578–1657) is commonly looked upon as the father of physiology. The ingenious experiments which he employed in demonstrating the circulation of the blood may be said to have established a methodology which was sound in principle and which showed the way for studies of bodily function. However, it was Albrecht von Haller (1708–1777), the versatile Swiss genius, poet, anatomist, botanist, biologist and physician, who first made physiological investigations on a broad and systematic basis, published the first text-book on the subject, awakened the curiosity of other students and stimulated others to investigations in this field. From this beginning, physiology has kept pace with anatomy in that intensive, critical and analytical studies have been applied to the body as a whole, to its parts separately and collectively and to its minutest components in an effort to find out their manner of working. Much real information has been gained, absorbing and astounding facts, which has permitted medicine to advance in much of its endeavor from speculation to certainty. But the story is far from completely told. The complications that are furnished by chemistry, physics and mechanics, associated with the intangible thing that we call life, leaves us with problems of infinite variety and ever widening complexity. It is probable that in this field medical science has more ground to till than in any of the others that it has thus far cultivated.

The knowledge of normal structure and of normal function are stepping stones in the evolution of modern medicine to an understanding of modifications of structure and function that are produced by disease processes. As far back as the fourth century B.C., Erasistratus had observed and described changes in organs that were found after death, for example, hardening of the liver in association with dropsy, and isolated observations of a similar nature are recorded by others of the ancients. In the latter part of the fifteenth century, Antonio Benivieni left a record of 111 observations of clinical cases with an effort to correlate the clinical and post-mortem findings in many of them. By the seventeenth century the practice of making post-mortem examinations had been greatly extended. But out of it came no systematic effort to relate the changes caused by disease to the signs and symptoms of the disease that were observed prior to death. Giovanni Battista Morgagni (1682–1771) came to a full realization that disease results in physical changes in the organs and tissues of the body, that these changes result in perversions of function and that they together result in the pictures that are seen in clinical medicine. Dr. Osler, in his "Evolution of Modern Medicine," cites a classical passage from Morgagni's writings:

> A lady, forty-two years of age, who for a long time had been a valetudinarian, and within the same period, on using pretty quick exercise of body, she was subject to attacks of violent anguish in the upper part of the chest on the left side, accompanied with difficulty of breathing, and numbness of the left arm; but these paroxysms soon subsided when she ceased from exertion. In these circumstances, but with cheerfulness of mind, she undertook a journey from Venice, purposing to travel along the continent, when she was seized with a paroxysm, and died on the spot. I examined the body on the following day. . . . The aorta was considerably dilated at its curvature; and, in places, through its whole tract, the inner surface was unequal and ossified. These appearances were propagated into the arteria innominata The aortic valves were indurated.

Commenting on these pathological changes, Morgagni says, "The delay of the blood in the aorta, in the heart, in the pulmonary vessels, and in the vena cava, would occasion the symptoms of which the woman complained during life; namely, the violent uneasiness, the difficulty of breathing, and the numbness of the arm." Here we have a clinical description of angina pectoris, a study of the physical changes in the organs that accompany the disease and a retrospective explanation of the symptoms that were caused by these changes.

Morgagni furnished the impetus for the study of pathology, the science of morbid structure resulting from disease It was a far cry from demons to tissue changes, but Morgagni was pushing aside philosophical concepts of disease and forging the tools by which speculation and theory were to be supplanted by hard facts and physical changes. The era of modern medicine may be said to have been born with Morgagni. From this beginning we have now progressed to a more or less detailed knowledge of the physical changes that are produced in the organs and tissue of the body by practically all the diseases from which man suffers.

Rudolph Virchow (1821–1902) realized early in his career that pathological anatomy was not expressive of a full understanding of disease processes and that it failed to offer an altogether useful basis for the most intelligent treatment of sick people. He saw the need for determining the alterations in function of organs and tissue that was brought about by the physical changes that disease produced in them In the introductory number of the "Archiv für pathologische Anatomie und Physiologie und für klinische Medizin," he said.

> The standpoint we propose to adopt, and which is clearly manifested in this first issue, is simply that of natural science Practical medicine as applied theoretical medicine, and theoretical medicine as an embodiment of pathological physiology, are the ideals toward which we shall strive so far as lies within the scope of our powers. Pathological anatomy and clinical work, although we fully recognize their justification and independence, are both mainly regarded as the sources of new problems whose answers must be supplied by pathological physiology. Since, however, these problems must for the most part be formulated by means of a laborious and comprehensive study of detailed phenomena in the sick and upon the post-mortem table, we maintain that a precise and purposive development of anatomical and clinical experiences is the first and most important requisite of the day. Through an empiricism of this sort there will gradually be brought into being a genuine theory of medicine, a pathological physiology.

Virchow's ideal has approached reality. Physiological principles and techniques have been applied to the clinic, specific means of investigating the function of different organs have been devised, and these measures now afford some of the most exact and valuable diagnostic criteria that clinical medicine has at its disposal.

Speculation as to the cause of disease, as is true of abstract thinking in general, gave little in the way of tangible and worth-while results. Until the middle of the last century we knew little more of the causes of infectious diseases than did the Greeks or the Egyptians before them. In 1857 Louis Pasteur published his paper on "Lactic Acid Fermentation," and, shortly thereafter, a paper on "Alcoholic Fermentation" in which he concluded that such fermentation is "correlative to a phenomenon of life." The turn of Fortune's wheel directed the genius of this man from the field of chemistry to that of microscopic biology, and his work laid the foundation on which has been built our knowledge of the living causes of infectious diseases. From a study of the diseases of wine, he turned to the study of diseases of the silkworm, from that to the diseases of animals, and finally to an investigation of rabies in man. He demonstrated the presence of viable agents in all these studies, and pointed out methods for controlling them. In addition, he arrived at an understanding of the mechanism of defense in the host which permitted of recovery from infection. On the work of Pasteur has been built the two great related sciences of bacteriology and immunity, the science of the cause of infectious diseases and the science of tissue reactions that arise in response to such infections.

The unremitting search for bacteria and other living parasites, as the cause of acute diseases in man, that owes its impetus to Pasteur's work and thought, has resulted in the demonstration of something more than twenty specific bacteria that produce characteristic disease pictures, has led to an understanding of other infectious diseases for which the specific bacteria have not been identified, and has been indirectly responsible for the discovery of filterable viruses, fungi, protozoan and metazoan parasites as the cause of human disease

I feel safe in saying that Pasteur's influence on medicine, as we know it to-day, has been even broader than stated above. The emphasis that was laid by him on the cause of disease led to the thinking in terms of causes for all diseases, and with him dawned the era of etiological or causative medicine. From the pragmatic standpoint, the control or cure of a disease can be attained only when its cause, at least in a general sense, is known. To-day, as physicians, we think in terms of causes, our medical nosology is built around them, and the success or failure of our efforts is in large part dependent upon the accuracy or inaccuracy of our conception of causes. Aside from diseases that are due to living organisms, we recognize physical causes of disease, chemical causes that are clear and definite, deficiencies in diet that produce specific changes, diseases of metabolism that are traceable to assignable causes within the body, and tissue changes that arise from excessive demands on certain parts of the body or that come as "slow gradations of decay" as age passes into senility.

In the clinic, we have learned to identify these living causes of disease. Bacteria are grown in cultures from the body's fluids or tissues or are visualized in smears by staining methods, and their by-products are demonstrated by biological reactions. The different forms of parasites are directly seen or their presence determined by the finding of their eggs. Here we have diagnostic procedures of the most direct and positive nature.

The study of the individual sick of disease is, of course, the immediate concern of diagnostic medicine. The problem here is divided into two broad categories, the discovery of the disease from which the patient is suffering and a determination of the manner in which the body of the patient has been altered in structure and function by the disease. It is necessary that we know disease, and it is necessary that we have at our disposal means for exploring the body. The evolution of methods, looking to these ends, is a fascinating story of ingenuity and accomplishment.

Thomas Sydenham (1624–1689), spoken of as the English Hippocrates, stated that "all disease could be described as natural history." With this in mind, he set out to make such descriptions, observing and recording cases from the appearance of the first symptoms to the disappearance of the last. Sigerist has said of Sydenham:

> Like Hippocrates his general outlook upon illness was that it was a natural healing process. Nevertheless there lay a whole world between the two. The decisive difference between them becomes plain in respect of their divergent outlook upon illness as soon as they quit the general. Hippocrates recognized only disease, not diseases. He knew only sick individuals, only cases of illness. The patient and his malady were for him inseparably connected as a unique happening, one which would never recur. But what Sydenham saw above all in the patient, what he wrenched forth to contemplate, was the typical, the pathological process which he had observed in others before and expected to see in others again. In every patient there appeared a specific kind of illness. For him maladies were entities, and his outlook upon illness was, therefore, ontological. Hippocrates wrote the histories of sick persons, but Sydenham wrote the history of diseases.

From this we have come to the modern clinical record, a careful compilation of racial, familial, occupational, climatic and other influences leading to disease, a description of the symptoms that accompany the disease, a detailed observation of the course of events that go with the disease, and facts concerning its duration and mode of termination. This clinical record, brought more and more to completeness as time and experience have permitted, has written the natural history of disease so that generalization has been possible, and many diseases are now recognized by the course of events that are produced by them. And the clinical record of a current case is now an important diagnostic adjunct, permitting the disease, as it were, to gradually identify itself by the trail that it leaves on the printed page.

When it comes to the study of the sick person, the physician can gain much information by the unaided use of his five senses, taste, touch, vision, hearing and smelling, but an enlargement of the field of these senses has been brought about by ingenious aids that magnify and penetrate so that things can be seen, heard and measured which were formerly inaccessible to such investigation. The developments in this line, the mechanical, physical, biological and chemical aids that clinical medicine has brought into use, have given real meaning to the term diagnosis, literally, to distinguish, to discern or to know apart. Let us look at some of these aids.

The study of the pulse in disease has gone on since early times. Herophilus, who gained fame as a physician, philosopher and teacher at Alexandria in about 300 B.C., held that the pulse was to be considered on the basis of rhythm, as in music, and carried his thesis to such lengths that only those trained in music could interpret the pulse as expounded by him. Galen (131–201) wrote seventeen chapters on the pulse, and no one was much the wiser for it. It is said that Galileo used his pulse to time the swinging of a pendulum and that Kepler timed his astronomical observations by the same means. Galileo's friend, Sanctorius, reversed the process, and used a pendulum to time his pulse. He devised an instrument, which he called the pulsilogium, consisting simply of a weight at the end of a thread which swung with increasing or decreasing frequency as the cord was shortened or lengthened, and by this means he was able to measure and record the rate of the pulse in terms of cord length. In the latter part of the seventeenth century, Sir John Floyer, of Staffordshire, made a so-called physician's watch, which ran for just one minute, none of the watches of that date having second hands on them. In 1855 Karl Vierordt introduced the graphic method of investigating the pulse, and this was shortly followed by Marey's sphygmograph. This has evolved into the so-called polygraph, an instrument which records simultaneously the pulse at the apex of the heart, in one of the larger peripheral arteries and in the great veins of the neck. From such tracings valuable diagnostic information can be gained.

Sanctorius, likewise, developed the first clinical thermometer, if the crude glass tube used by him to measure the amount of warm air that the patient expired can be recognized as such. George Martine (1702–41), of Scotland, revived Sanctorius' ideas, and James Currie made practical use of the thermometer in the treatment of fevers with cold water. Carl August Wunderlich (1815—1877), of Leipzig, was the first to make systematic thermometric observations at the bedside, to keep temperature charts and to determine finally the types of febrile reactions in different diseases. Modifications of the clinical thermometer are now available for different types of work, and such delicate instruments as the dermatherm have been devised so that minor changes in the surface temperature of the skin can be determined.

Inspection or looking, palpation or feeling, percussion or the listening to notes that are produced by tapping, and auscultation or the listening to sounds that are generated within the body are the four pillars of physical diagnosis. Dr. Osler has said that many more mistakes in diagnosis are made from not looking than from not knowing, and certain it is that simply by looking we can gain much diagnostic information. By palpation, the art of feeling with the hands, much can be found out about disease processes on the surface of the body and to a less extent inside of it, notably by feeling through the soft abdominal walls and inside of the various body orifices. But until the eighteenth century the bony wall of the chest effectively shielded the organs inside of it from the curious eyes, ears and fingers of the physician.

In the middle of the eighteenth century, Leopold Auenbrugger (1722-1809), a Viennese physician, remembering how his father, an inn-keeper, determined the level of wine in casks by tapping on them, applied the principle of tapping or percussion to the examination of the chest. Through painstaking experiment and collection of data he gave to medicine the art of percussion. By this simple means we have learned how to map out the size and position of the heart, to discover the presence of tumors in the chest and to detect the replacement of air-containing lung tissue by the products of inflammation or fluid.

Supplementing the discovery of Auenbrugger was that of Laennec (1781–1826), the French student of disease who was impressed with the importance of listening to sounds that were generated by diseased hearts and lungs. In passing through the court-yard of the Louvre, he observed a group of children who were engaged in signalling to each other through a hollow beam. Hurrying to the hospital he made a cylinder of a piece of paper, applied one end to the chest of a patient and the other end to his ear. New fields were opened to his hearing, the stethoscope was born, and the real art of auscultation was introduced into medicine.

This quadrad of physical diagnosis, inspection, palpation, percussion and auscultation was firmly established by the early years of the nineteenth century; it remains the basis for the clinical examination of patients, and a physician's excellence may in large part be judged to-day by the skill and judgment that he displays in using it. Supplementary aids have come in large numbers, chemical, physical and biological procedures that test it and elaborate it, none to supplant it, all adding glamor and strength to this natural equipment of the physician in his diagnostic efforts.

The application of chemistry to diagnostic medicine has brought new significance to the study of the urine. We need no longer say with Webster in the "Duchess of Malfi," "the urine is the physician's whore, for she cozens him"; nor need we send such messages as the page took to Falstaff, when, in reply to the question, "Sirrah, you giant, what says the doctor to my water?", the page replies, "He said, sir, the water itself was a good healthy water; but for the party that owed it, he might have more diseases than he knew of" Likewise, chemical studies of the blood, the saliva, the gastric juice, of the body fluids and effluvia in general and of the respired air have brought us methods of precision and of inestimable value as diagnostic procedures.

Physics has found its place over a wide range in clinical medicine. The sphygmomanometer, an instrument for measuring the pressure of the blood within the arteries, owes its origin to the work of Stephen Hales (1677–1761) who, in 1733, described his experiments in determining the arterial blood pressure in horses by the simple expedient of fastening a long glass tube inside of an artery and reading directly the height of the column of blood. The column of blood has been reduced to a column of mercury, which is connected by rubber tubing to a distensible sack, which, after being applied to an arm or a leg, is inflated until the flow of blood in the main artery underlying it is shut off. The pressure required to do this is thereby registered by the column of mercury in a millimeter tube. Light, either direct or reflected or in the form of electrically lighted instruments, has opened the portals of the body to direct inspection, deep down into their recesses. Electricity has given us the x-ray as a means of penetrating vision, galvanic and faradic currents for the study of nerves and muscles, and such instruments as the electrocardiograph for the study of action currents that are generated by the contraction of the heart muscle. Polariscopes, spectroscopes and colorimeters now play an integral part in diagnostic efforts. The microscope has a multitude of uses in clinical medicine and is essential in the proper examination of every patient.

Of course, we have done nothing more than touch the high spots in showing the application of physics to medicine, but it is probably enough to indicate the avidity with which medicine avails itself of every opportunity for supplanting inexact observations and opinions with physically exact measurements and records.

Studies in the fields of serology and immunology have brought us some of our most important diagnostic aids. Paul Ehrlich (1854–1915), through the elaboration of differential stains, recognized the varieties of white blood cells that normally occur in the circulating blood, and showed how these normal values were modified, in quality and in quantity, by bacterial invasions of different kinds and by certain chemical poisons His studies led him to a theoretical explanation of immunity, or the mechanism by which the body develops a resistance to the disease processes which attack it. Emil Behring (1854–1917), working at the same time as Ehrlich, specifically studied the antitoxins that are to be found in the blood serum in response to the introduction of toxins of bacterial origin. Means have been found for identifying these products of reaction in the blood serum, and it has been shown that they are specific, and recognizable as such, for the type of bacterium to which the body is reacting. From these investigations have come the diagnostic methods of blood counting, of agglutination reactions, of complement fixation tests and tests for tissue sensitivity to specific toxins, measures that often enable us to say with certainty what bacterium or toxin is responsible for the disease before us.

In summary, then, the physical diagnosis of disease is based to-day upon the naturalistic conception that all disease has a natural origin, runs a natural course, produces natural reactions in the body, results in natural changes in the body tissues and terminates by processes that are naturally understandable and detectable. The studies of anatomy, physiology, pathology, bacteriology and serology have yielded a vast fund of knowledge in support of this conception and have enabled us to recognize the effects of disease while they are in progress. The sciences of physics, chemistry and biology have widened the scope of diagnostic medicine and have led to scientific certainty in many of its investigations. Of course, with all this, much yet remains to be done, and much is being done day by day. Medicine now shares with science in general a pride in its accomplishments, a satisfaction in the knowledge that it has gained through painstaking investigation and honesty of effort and the humble realization that the future will modify some of its concepts, strengthen some and destroy others.

I have purposely left out of consideration the personal equation of the physician in diagnostic medicine. This would carry us into the intangible field of individual knowledge and judgment, and a discussion of it would lead nowhere. Suffice it to say that medicine has made for better doctors as medicine itself has grown into a better medicine. I have also failed to consider the mental and emotional fields of diagnostic medicine, not because they are lacking in importance, but because they do not lend themselves to the scientific approaches with which we have been dealing. It has been my purpose to show that physical diagnosis has in large part been mechanized, and to indicate the exact methods that clinical medicine has at its disposal today for determining the cause and nature of disease.

THE MAYA COUNTRY IN YUCATAN

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THE Mayas have long occupied the Yucatan Peninsula and adjacent parts of Central America, particularly Guatemala and Honduras. The peninsula is for the most part a flat sheet of limestone which was raised out of the ocean in the Pleistocene epoch of geological history. It is so recent that it has not yet had time in most places to accumulate more than a very thin layer of soil. During the dry season when the sun shines on the surface of the ground, it gets very dry and hot. No point in the State of Yucatan is more than a thousand feet above sea level. The shrubs and trees are therefore semi-xerophytic in character. There are no rivers in Yucatan, but long brackish cienagas extend along the coast. Toward the base of the peninsula the forest grows heavier; rivers flow into the cienagas. Here grows the sapote tree, the secretions of which (*chicle*) furnish the basis for chewing gum; also Spanish cedar, mahogany and other valuable woods. Guatemala and Honduras are for the most part rather wet and when not disturbed by man are usually covered by swampy areas and heavy forests.

The Mayas have a glorious past. Before Columbus came to America they had built magnificent and ornate architectural works, all without the use of metal tools, wheels or keystone arches. They constructed fine roads, which were often paved and graded. In Yucatan there were two periods when Mayas built up great empires. The Old Empire thrived from about 350 A.D. to 670 A.D. Then there was a migration south for several hundred years, but from about 965 A.D. to 1450 A.D. the New Empire flourished and many of the great architectural monuments that stand to-day were built. All over Yucatan one encounters vegetation-covered mounds with bits of masonry showing here and there. The most accessible of the great ruins are at Chichen-Itza, where many buildings and monuments have been wholly or partially rebuilt by the Carnegie Institution and the Mexican Government, and at Uxmal.

The ancient Maya system of government was somewhat like that in medieval Europe. Great cities like Uxmal, Coba and Chichen-Itza were centers for trade, government and religion. The noblemen were priests, political administrators and warriors. Thousands of slaves captured during wars were used in constructing buildings and roads. Mercenary soldiers were brought in from other parts of Mexico. The culture of the Old Empire was largely Mayan, but during the golden age of the New Empire many Toltec institutions were introduced from the mainland of Mexico. Among these human sacrifice, ball courts and the feathered serpent may be mentioned.

When Montejo established Spanish colonies in Yucatan in the seventeenth century the glory of the New Empire had already departed. The Mayas in their best days supported a high order of culture. The architectural works are well known. The Mayas used two calendars, religious and fiscal, which were carefully integrated. Astronomers were able to predict eclipses accurately. Most of the stone monuments which the Mayas left in various places are covered with dates of important historical events; such as the inauguration of kings and great battles. The written hieroglyphic codices of the Mayas were largely destroyed by bigoted Spanish priests while they were converting the Indians. Only three of these old manuscripts remain. In the later days of the empire jealousy and wars between the cities, and perhaps contributing causes, such as disease and famine, paved the way for the disintegration of high culture. When Montĕjo made his *entrada* the great buildings at Chichen-Itza and Uxmal were already overgrown with vegetation and falling into ruins.

The greatest hero in Mayan history is Kukulcan. He is said to have been brought to Chichen Itza as a captive and thrown at dawn into the Sacred Cenote as a sacrifice to the rain god. At noon he was alive. There had been a prophecy that if a man survived the cenote ordeal he was to be a great leader for the Mayan people. Kukulcan was accordingly taken out of the cenote and honored as a king. He proved to be a very wise and competent ruler. The Mayan Empire flourished under him. Later he was believed to be a god, in fact none other than Quetzalcoatl, who had condescended to appear in the form of a man to help the Mayas. Now he is a semi-mythological character.

At present, as in the past, the great problem for the Mayas in Yucatan is to get water. As there are no rivers, people depend on *cenotes,* great well-like perforations through the limestone which reach ground water; *aguadas,* shallow water holes which are often filled with aquatic vegetation; and *cuevas* (caves), where water drips slowly from the roof into pots or sometimes stands in little natural pools. As one travels through the country he finds that where there is a village there is usually a cenote.

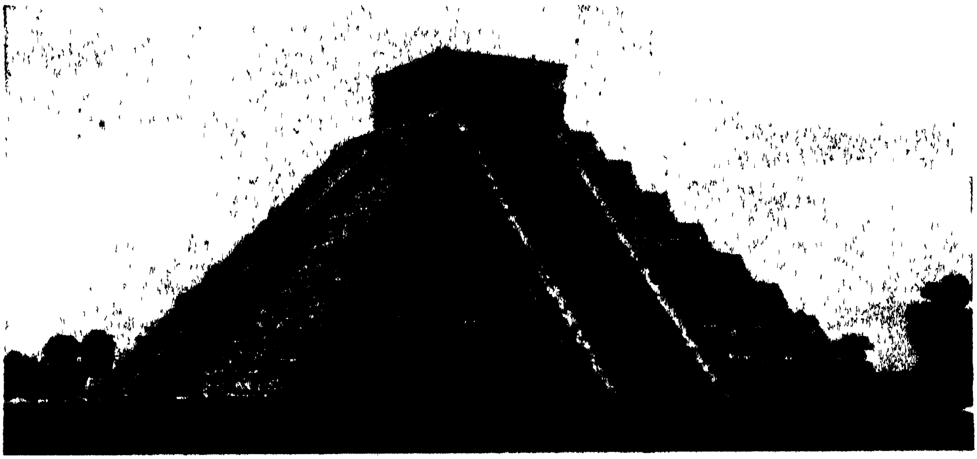
The Mayas have from ancient times raised two crops on the thin rocky soil of Yucatan and they continue in much the same way to-day. Corn (*maise*) is raised by milpah farming. A tract of land is cleared of timber, which may be of value for building or fuel and then burned over. Corn is planted at the beginning of each rainy season (May) between the stumps and rocks for about two years, when the growth of other plants makes it difficult to continue to cultivate. A new milpah is then prepared. On account of limited water supply the ears of corn are usually rather small and the kernels hard, but the flavor is excellent. Another staple crop is hennequin, a fiber-producing plant, which requires seven to nine years to reach bearing size and then continues to produce fibrous leaves for about twenty years. Fruits are also often raised in the yards about houses—oranges, papayas, melons, soromoyas, mangoes, mames, aquacates, bananas, etc. Among the trees there are always chickens and pigs; also often goats and other domestic animals. Cattle are raised on haciendas everywhere. Toward the south in Quintana Roo and Campeche *chicleros* make a living by collecting chicle from the sapote tree, and there are many cattle.

It is pleasant to travel through the Maya country. Though one must often suffer minor inconveniences from mosquitoes, sand-flies, bedbugs, fleas, ticks, bad water and poor food, the little Indians are always honest, courteous and hospitable. A modern Maya wears a characteristic dress. He is generally very clean. The women are usually wide and dumpy. They wear a loose white gown, which has printed patterns or embroidery about the low neck and around the bottom. Often a fancy petticoat extends below the dress. Poor women are barefoot, but those who can afford to do so wear sandals (*alpargates*) or perhaps even high-heeled shoes. When going abroad, as to market or to the mill where her *maise* is ground, a woman usually wears a bright-colored scarf over her head and about her shoulders Often she carries a water pot on her hip or a dish of *maise* on her head A man wears a white cotton shirt and pants, a large straw sombrero or no hat at all, sandals and a characteristic cotton apron which extends to his knees across the front, along one side and across the back but is open on the right side Heavy burdens are carried on the back and supported by a strap across the forehead

When one travels into the interior of Yucatan, he finds accommodations very simple Even in hotels he expects nothing but food and two hooks on the wall. He hangs his own hammock, which he carries with him in a bag Food always includes tortillas and frijoles; perhaps also chicken, pork, beef, squash, aguacates, tomatoes or other fruits Mayas generally drink *pozole*, which consists of raw corn meal in cold water This beverage becomes quite sour after a few hours Affluent persons imbibe chocolate at the end of a meal The chocolate

A YOUNG MAYAN WOMAN

MAKING ROPE FROM SISAL.



EL CASTILLO, CHICHEN ITZA; SAID TO HAVE BEEN BUILT BY KUKULCAN.

is flavored with cinnamon in the usual Mexican style and makes a very agreeable drink. The foods of the Mayas are not prepared or served in a very sanitary way. Intestinal diseases are therefore prevalent, especially amoebic dysentery.

Mayas are Roman Catholics. Little shrines often occur along roadways, and almost every thatched hut contains a simple one. Pictures of virgins and crosses are supported by candles and flowers in old liquor bottles. Large haciendas often provide churches for the Indian laborers. In the large towns there are cathedrals, many now wholly or partly in ruins with the recent decline of the church in Mexico. In some localities church buildings are now used for schools, restaurants and other purposes.

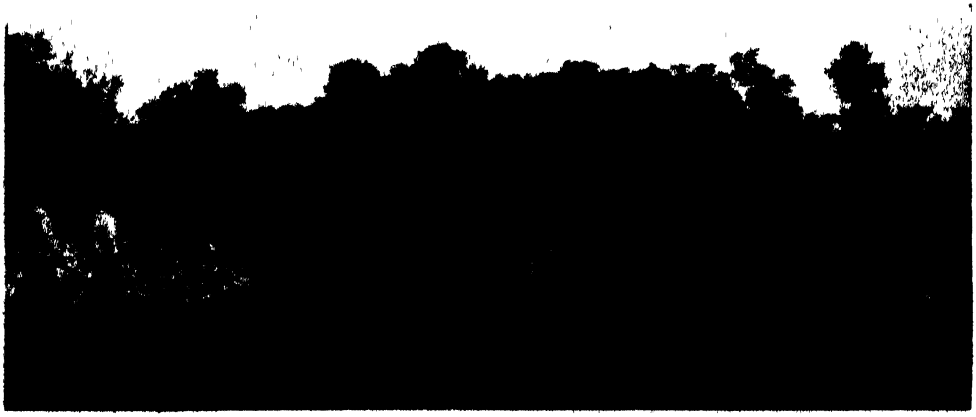
THE INITIAL SERIES LINTEL, 619 A.D.; CHICHEN ITZA.

Where land has not been cleared for milpahs or hennequin haciendas it remains in a rather primitive state, covered by low trees and shrubs. There are a few roads suitable for automobiles, but most of the country roads are difficult even on horseback or in a cart. During the rainy season they consist of alternating strips of shallow canals and rough rocky ridges. Most Mayas make their journeys on foot with their burdens on their backs. Parts of Quintana Roo have never been conquered or surveyed by Spaniards or Mexicans.

As one goes along the country roads afoot or on a horse thorny shrubs reach out and snatch his hat off or tear holes in his shirt. Along the way giant cacti are interspersed with acacias, agaves and other semi-xerophytic plants. Leaf-

CATHEDRAL AT OXKUTZCAB.

cutter ants march in long armies bearing bits of leaves to the fungus beds within their great nest mounds. Doves and quail are common. Morning and evening cardinals and other beautiful song birds make the trails pleasant, but at midday little life is to be seen. One often meets an Indian with a deer. Occasionally a peccary, porcupine, agouti or fox may be seen. *Sapolotes* (buzzards) are everywhere. In the rocky crevices of cenotes twittering swallows and motmots build their nests. The latter are beautiful, hoarse-voiced, iridescent birds with long tails which they continually wag from side to side.



SOCIALIST GOVERNMENT SCHOOL; KAUA.

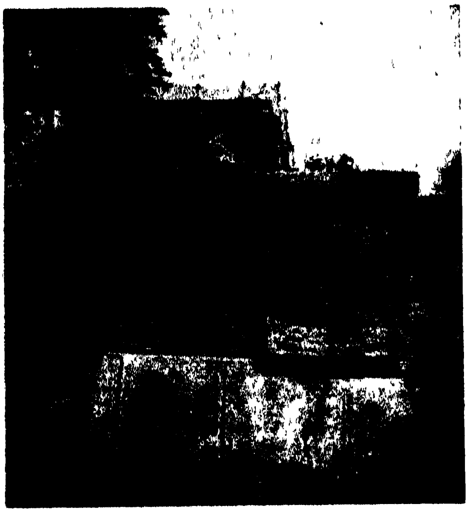
MAYA FIGURINES.

The porous limestone which underlies the thin soil throughout Yucatan permits water to percolate readily. Rains quickly descend to near sea level and usually there is no water available at the surface. Before wells were built Mayas were dependent on cenotes and caves for water. Wild animals are still obliged to seek water in caves during the dry season. There are also a number of species which live permanently in the underground waters and wander about from place to place through crevices in the rock *Bagres* (catfishes) often live in cenotes and caves. Blind cave fishes have also been found. Blind shrimps, blind schizopods and isopods are widely distributed and are often captured in caves and wells. A Maya woman drawing water from a hundred feet below

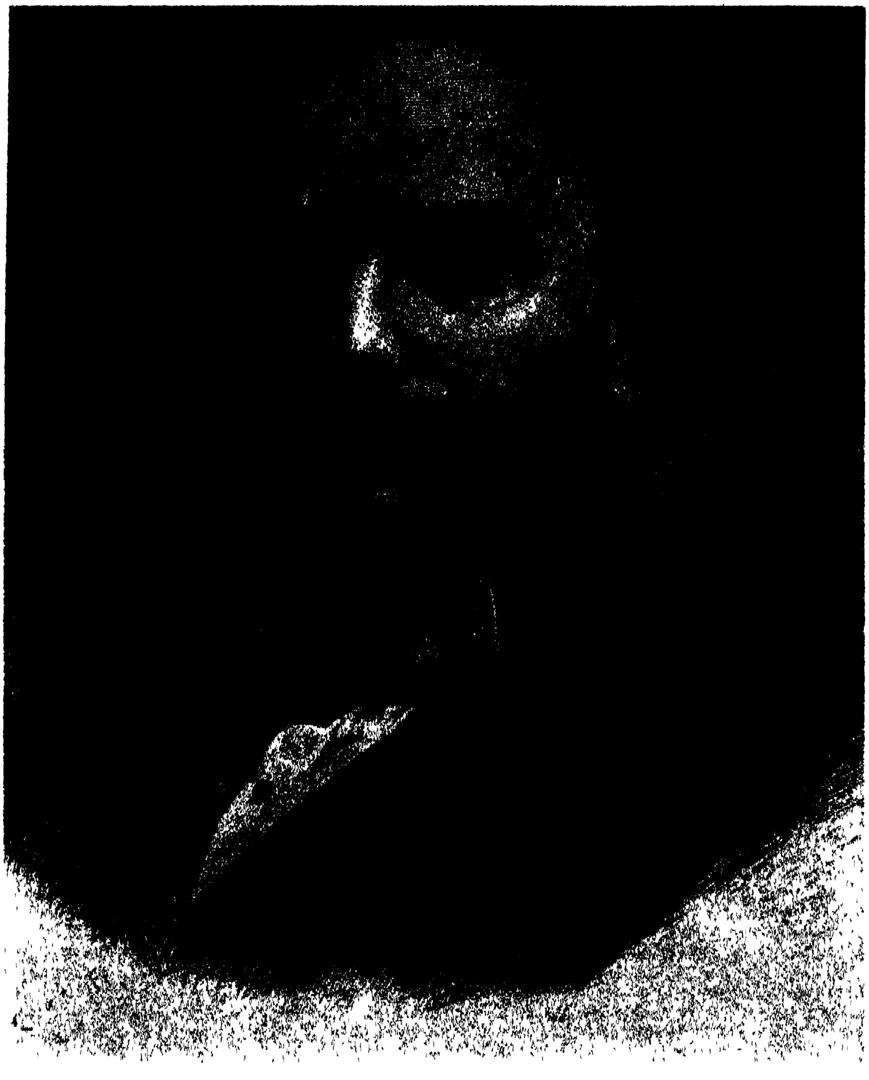
MAYA GIRL SEATED ON A CHAC MOL; TEMPLE OF WARRIORS, CHICHEN ITZA.

may find a white, blind crustacean swimming about in her bucket.

At present social and political conditions are changing in Yucatan. The old order wherein wealthy *haciendados* dominated great plantations and were the local rulers of hordes of illiterate peons is giving way to a new socialistic government. State schools are being established everywhere, and parochial schools have lost their influence or have been closed altogether. There are two types of teachers; some hired by the federal government and some by local authorities. In certain districts the teachings of the former were so unpopular that the teachers were killed by the natives. Labor unions dominate certain activities and are often not well organized. The baggage handlers union pesters the traveler with petty fees for unnecessary services at docks and railway stations. Most of the *haciendas* are deserted by the owners because their laborers no longer look upon them as benign patrons, but demand impossible privileges or wages and even attack their employers. Village police usually suspect that any stranger is looking for gold, and *presidentes* demand that a stranger appear before them to explain his business. In addition to bull-fighting and baseball, one of the open sports is shooting governors and other officials. Men of property are discouraged because the federal government is confiscating their lands and apportioning them among Indians. During the year 1936 little or no hennequin was planted in Yucatan by the *haciendados*. They felt that it would be wasted effort because their lands would soon be confiscated and given to poor men who will have neither knowledge or means to manufacture hemp or market it. So times are bad in Yucatan; but the country and the people are good.



JAGUAR AND EAGLE HOLDING HUMAN HEARTS; CHICHEN ITZA.



THE LATE LORD RAYLEIGH

PRESIDENT OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE IN 1884. REPRODUCED FROM THE POPULAR SCIENCE MONTHLY (NOW THE SCIENTIFIC MONTHLY), OCTOBER, 1884.

THE PROGRESS OF SCIENCE

FATHER AND SON AS PRESIDENTS OF THE BRITISH ASSOCIATION

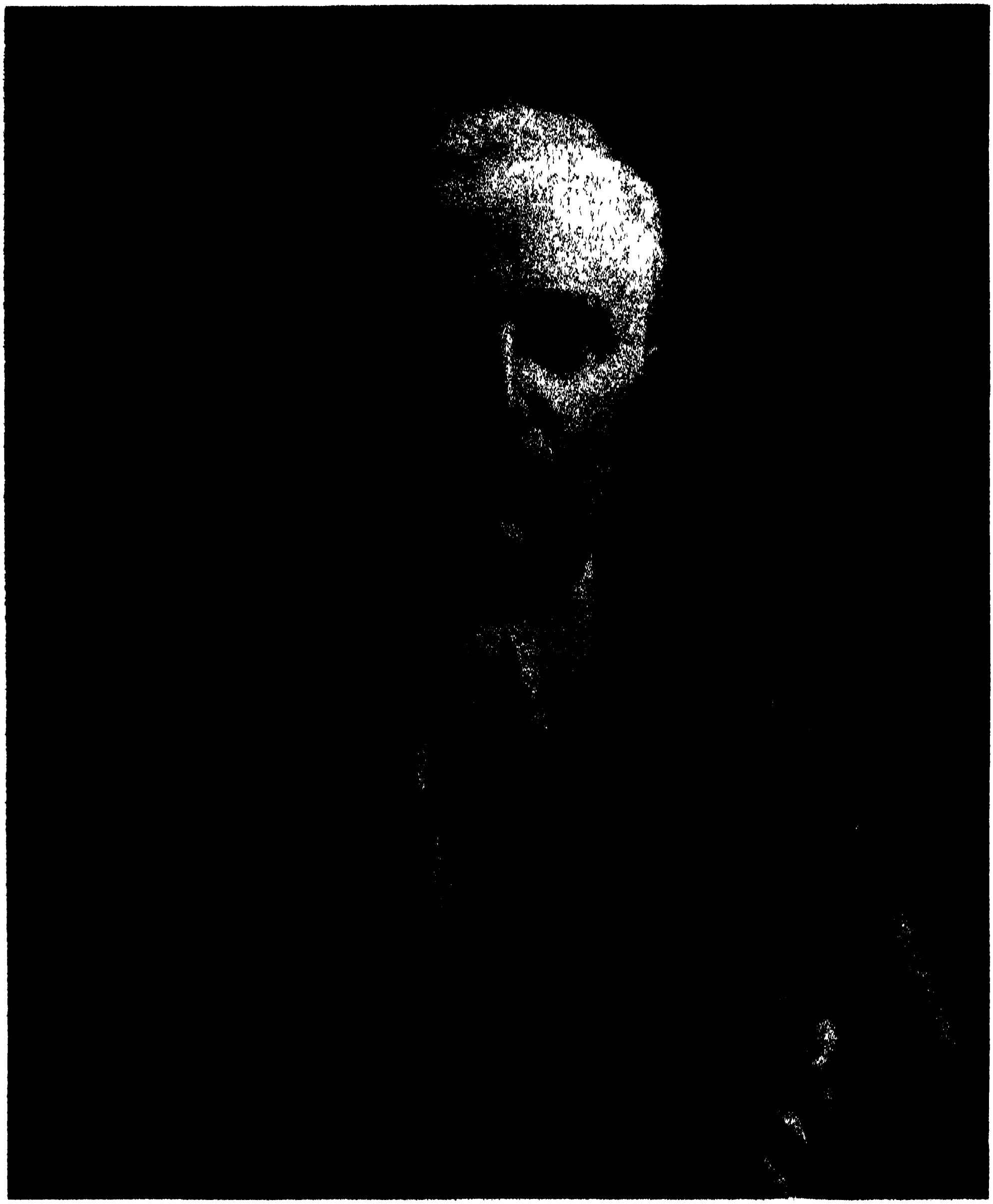
LORD RAYLEIGH has been elected president of the British Association for the Advancement of Science to succeed Sir Edward Poulton. Lord Rayleigh's father was also president of the association; his presidential address, given in Montreal in 1884, is reprinted as the leading article in this issue of THE SCIENTIFIC MONTHLY. The address was originally in the POPULAR SCIENCE now THE SCIENTIFIC MONTHLY for October, 1884.

The address, covering as it does the development of physics at that time, is particularly interesting in view of the continuous progress of physics, for it was Lord Rayleigh, Sir William Thomson (later Lord Kelvin), James Clerk Maxwell, Sir J J. Thomson, Willard Gibbs, Hertz, von Helmholtz and their contemporaries who laid the foundations of the modern science of physics

In introducing Lord Rayleigh at the first assemblage of the association at Montreal, Sir William Thomson said: "Professor Cayley [who preceded Lord Rayleigh in the presidency] has devoted his life to the advancement of pure mathematics. It is indeed peculiarly appropriate that he should be followed in the honorable post of president by one who has done so much to apply mathematical power in the various branches of physical science as Lord Rayleigh has done. In the field of discovery and demonstration of natural phenomena Lord Rayleigh has, above all others, enriched physical science by the application of mathematical analysis. . . . In reading some of the pages of the greatest investigators of mathematics one is apt occasionally to become wearied, and I must confess that some of the pages of Lord Rayleigh's work have taxed me most severely, but the strain was well repaid. When we pass from the instrument which is harsh and crabbed to those who do not give themselves the trouble to learn it thoroughly, to the application of the instrument, see what a splendid world of light, beauty and music is opened to us through such investigations as those of Lord Rayleigh! His book on sound is the greatest piece of mathematical investigation we know of applied to a branch of physical science."

This feature of his work, its extreme accuracy and definiteness, the combination of mathematical acumen with experimental skill is the measure of its greatness. A large part of his work consisted in the examination of things concerning which the superficial facts were already known. In this way he furnished a great mass of detailed and precise material. In fact, he covered the greater portion of the entire field of physics filling in many gaps by experiment, calculation and thought. The subjects to which he contributed include chemical physics, capillarity and viscosity, the theory of gases, the flow of liquids, photography, optics, color vision, the wave theory, electricity and magnetism, electrical measurements, elasticity, hydrodynamics and sound, the last named being the subject of his most extensive work, "The Theory of Sound," a mathematical treatise published in 1877–1878. While this is his most important work the discovery of argon in 1904 is the most widely known. The numerous memoirs in which his original work appeared were later published together under his editorship. The last of these volumes appeared in 1903.

Lord Rayleigh's earlier papers were written under the name of J. W. Strutt, for he succeeded to the title in 1872, after he had become well known as a physicist.



—*Photo from Wide World Photos*

LORD RAYLEIGH

PRESIDENT OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

He was born on November 12, 1842. He did not attend a public school because of poor health; however, he attended Trinity College, Cambridge, and was graduated in 1865 with distinguished honors. Following the usual custom, when a student of a college has distinguished himself in the final examination, Trinity College elected him to a fellowship, which he relinquished on his marriage in 1871. He succeeded Clerk Maxwell as Cavendish professor of experimental physics at the University of Cambridge, occupying this chair from 1879 to 1884. In 1887 he became professor of natural philosophy at the Royal Institution of Great Britain, from which he resigned in 1905. He devoted much time to the organization of the Cavendish Laboratory, the gift of the eighth Duke of Devonshire, chancellor of the University of Cambridge, whom Lord Rayleigh succeeded in the chancellorship in 1908. He was elected a fellow of the Royal Society in 1873, and was president of the society from 1905 to 1908. He was one of the original members of the Order of Merit, instituted in connection with the coronation of King Edward VII. He received the Nobel Prize in 1904.

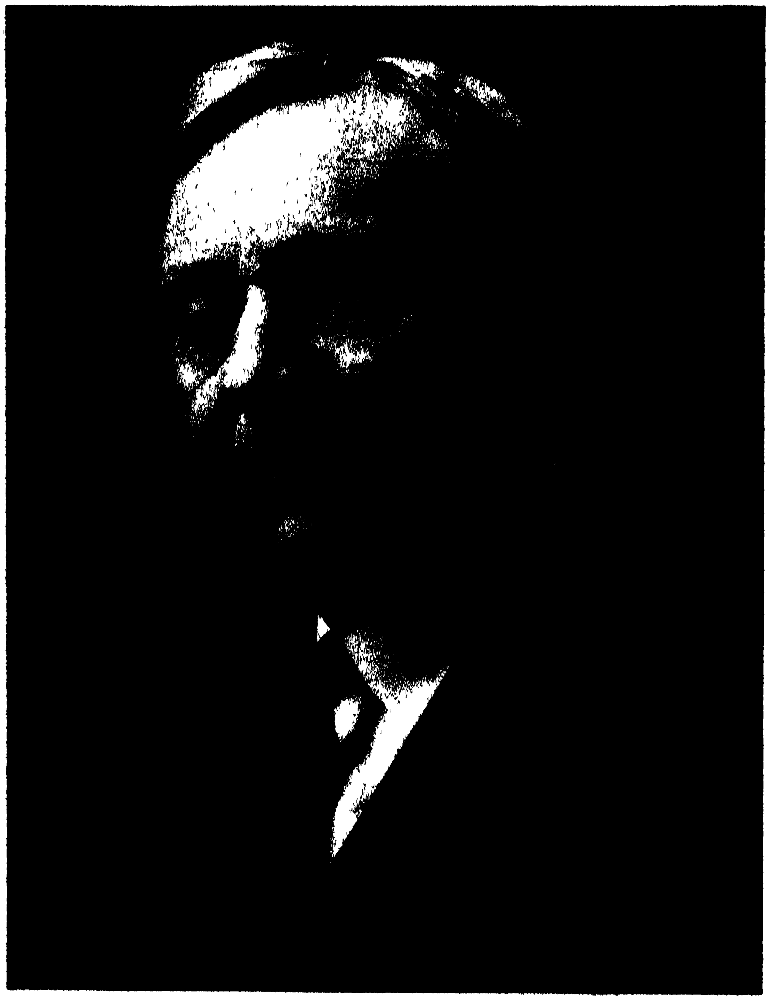
The present Lord Rayleigh was born on August 28, 1875, and attended Eton and Trinity College, Cambridge. He is now emeritus professor of physics at the Imperial College of Science, South Kensington. He was Bakerian lecturer in 1911 and 1919 and has been at various times foreign secretary of the Royal Society, president of the Section of Mathematics and Physics of the British Association for the Advancement of Science and president of the Physical Society. He is chairman of the governors of the Imperial College of Science and Technology and of the executive committee of the National Physical Laboratory.

Lord Rayleigh's influence on the development of physical science has been profound. As is stated in *Nature:* "First and foremost an experimental physicist, he has his father's flair for recognizing those aspects of an experimental investigation which most need stressing and for extracting results of fundamental importance from apparatus of simple, even primitive type. His work on radium and the earth's heat is classic in quality, and he has elucidated many diverse, and yet related, phenomena in his studies of the aurora borealis, the light of the night sky, the green flash and the fluorescence of mercury vapor. He has lately studied the conditions of optical contact of glass surfaces, and has investigated, by admirably simple methods, the pull required to separate, and the work done in separating, contacted surfaces. He has measured the small amount of reflection between two contacted glass surfaces and has shown that the blackness of the black center of the Newton's rings formed between a spherical and a plane surface is by no means perfect."

J. G.

UNIVERSITY PRESIDENTS WHO HAVE BEEN PSYCHOLOGISTS

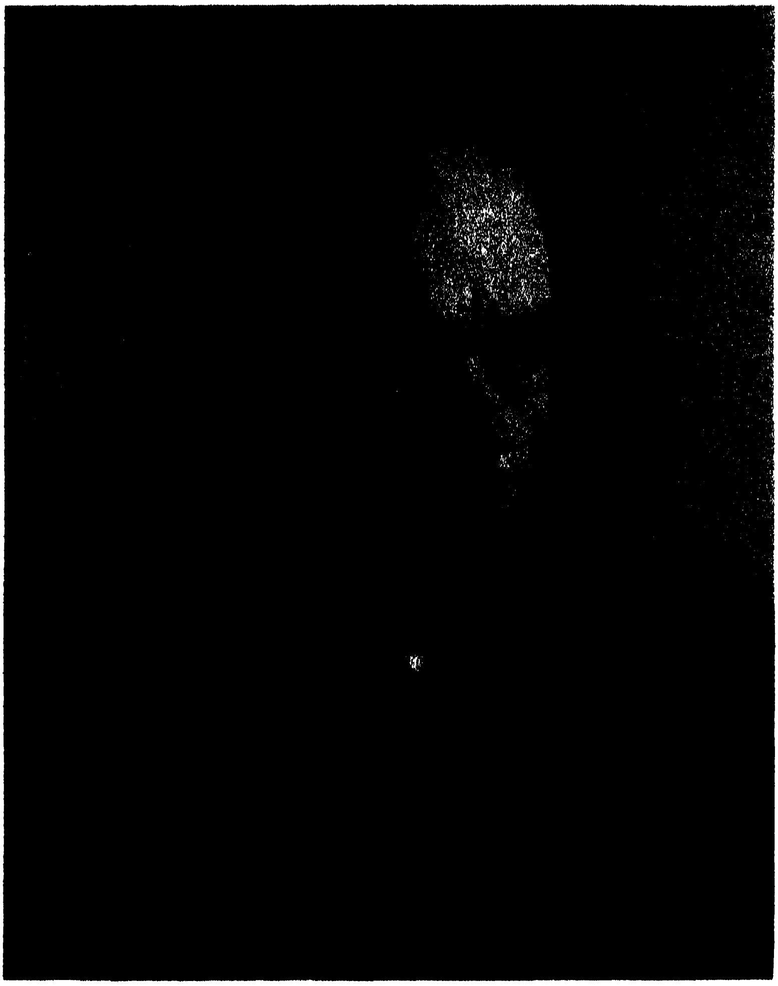
In the old days the college president was nearly always a clergyman, usually one who was or had been a professor. The president of Lafayette College, in whom the writer of this note is interested above all others, was typical—a professor of the classics, then for three years a Presbyterian pastor, then in 1863 called to the presidency of the college, being also professor of philosophy. Eliot was the first lay president at Harvard, Hadley at Yale, Wilson at Princeton. With the founding and growth of the state universities and the development of the colleges from the status of theological preparatory schools, with the advance of science, technology, medicine and law, many colleges became universities and a new type of president was sought. Those mentioned above are typical, as are Gilman at the Johns Hopkins, White at Cornell and Angell at Michigan. These



DR. WILLIAM LOWE BRYAN
PRESIDENT OF INDIANA UNIVERSITY FROM 1902 TO 1937. DR. BRYAN GRADUATED FROM INDIANA UNIVERSITY IN 1884; STUDIED IN BERLIN, WÜRZBURG AND PARIS AND RECEIVED THE DOCTOR OF PHILOSOPHY DEGREE AT CLARK UNIVERSITY IN 1892 UNDER STANLEY HALL. HE THEN BECAME PROFESSOR OF PHILOSOPHY AND PSYCHOLOGY AT INDIANA UNIVERSITY. HE WAS PRESIDENT OF THE AMERICAN PSYCHOLOGICAL ASSOCIATION IN 1903. HIS EARLY WORK ON THE MEASUREMENT OF MOTOR ABILITY AND THE PRACTICE CURVE HAS BEEN OF FUNDAMENTAL IMPORTANCE IN EXPERIMENTAL PSYCHOLOGY.

presidents were scholars, but the increasing complexity of the universities seemed to require men who were primarily executives; some rich business men were selected, as Low, a tea merchant, at Columbia; Harrison, a sugar merchant, at Pennsylvania.

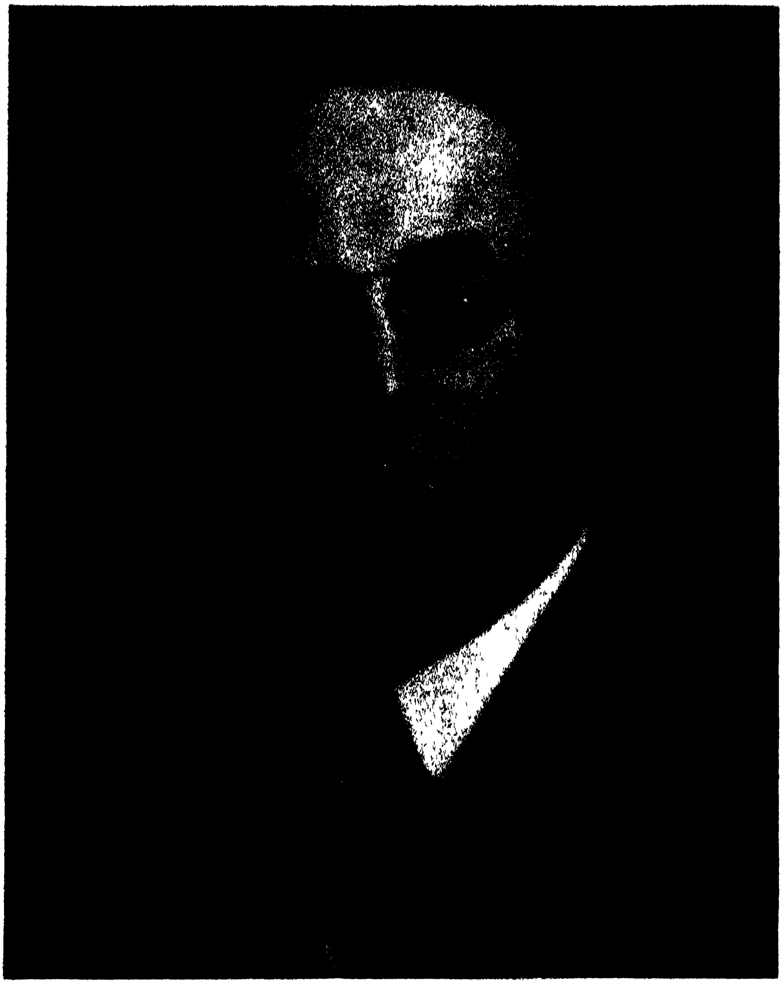
At that time there emerged a new science—psychology—the rapid progress of which in America being in part due to the fact that the president was no longer a clergyman who taught mental philosophy. The first chair of psychology, here or abroad, was established for Cattell at the University of Pennsylvania in 1888; he moved to Columbia in 1891. Then in rapid succession chairs of psychology were established in nearly all our lead-



DR. LIVINGSTON FARRAND
President of Cornell University from 1921 to 1937. Dr. Farrand graduated from Princeton University in 1888 and the Columbia Medical School in 1891, having been at the same time a student of psychology in the university, which study he continued at the University of Cambridge. He became instructor in psychology in Columbia University in 1903 and later professor of psychology and of anthropology. He was president of the University of Colorado from 1914 to 1919 and then chairman of the executive committee of the Red Cross He was secretary of the American Psychological Association from 1895 to 1904. A paper by Cattell and Farrand, entitled "Physical and Mental Measurements of the Students of Columbia University," published in 1896, is generally regarded as having laid the foundation for work on individual differences and the use of psychological measurements in schools and colleges.

ing universities. In 1889 William James was transferred from an associate professorship of philosophy to a chair of psychology at Harvard and published the following year his great work on psychology. Münsterberg was called from Germany to Harvard and Titchener from England to Cornell in 1892. Within this short period from 1888 to 1892 chairs of psychology were established at Wisconsin, Indiana, Nebraska, Brown, Wellesley, Stanford, Clark, Illinois, Toronto, Princeton and elsewhere.

Contemporaneously with this remark-



DR. JAMES ROWLAND ANGELL

DR. ANGELL GRADUATED IN 1890 FROM THE UNIVERSITY OF MICHIGAN, WHERE HIS DISTINGUISHED FATHER, JAMES BURRILL ANGELL, WAS PRESIDENT. HE RECEIVED THE MASTER'S DEGREE FROM HARVARD UNIVERSITY AND WAS PROFESSOR OF PSYCHOLOGY AND DIRECTOR OF THE PSYCHOLOGICAL LABORATORY AT THE UNIVERSITY OF CHICAGO FROM 1901 TO 1920, HAVING BEEN ALSO DEAN AND AT ONE TIME ACTING PRESIDENT. HE WAS CHAIRMAN OF THE NATIONAL RESEARCH COUNCIL IN 1919 AND PRESIDENT OF THE CARNEGIE CORPORATION IN 1920. HE WAS PRESIDENT OF THE AMERICAN PSYCHOLOGICAL ASSOCIATION IN 1906 AND VICE-PRESIDENT OF THE INTERNATIONAL CONGRESS OF PSYCHOLOGY MEETING AT YALE UNIVERSITY IN 1929.

able advance of psychology there was a corresponding development of the teaching of education—pedagogy it was then called—in our universities. It began in the state universities, but received its most notable advance in the appointment of Professor Hanus at Harvard in 1891 by President Eliot against the opposition of the faculty. Dr. Butler in 1890 became professor of philosophy and education at Columbia; he had established *The Educational Review* in 1889. Dr. Russell became dean of the newly established Teachers College at Columbia in 1897.

Psychology and education, which should be an applied science based primarily on psychology, seemed the most logical fields from which to draw the president of a university, if he were to be an educational leader rather than an orator and collector of money. Stanley Hall became president of the newly established Clark University in 1888, Dr. Butler president of Columbia in 1902. There have since been other professional students of education who became university presidents, as Dr. Coffman at Minnesota, Dr. Elliott at Purdue and Dr Capen at Buffalo. A number of psychologists were elected to be presidents at that time or later, three of whom have just now retired; President Bryan at Indiana, President Farrand at Cornell and President Angell at Yale. Others are President Scott at Northwestern, President Lindley at Kansas and President Chase at New York University.

University presidents are now drawn from nearly all sources. The principal of McGill University, Mr. Douglas, elected last month, is a business man and publicist, but there appears to be a tendency to select professors from the departments of political science, economics and history, as Dr. Seymour at Yale, Dr. Day at Cornell, Dr. Dodd at Princeton. Dr Conant at Harvard, however, is a chemist. The change in the attitude and function of the American university since the Johns Hopkins University was opened in 1876 is indicated by the fact that Dr. Conant is a research chemist of distinction, whereas Eliot was a teacher of chemistry.

J. McK. C.

SCIENCE IN PALESTINE

With Palestine a natural laboratory, great scientific strides have been made by the Hebrew University in Palestine since its inception ten years ago—strides that have had a marked effect on the industrial, social and commercial development of the country. In this comparatively short time there are already visible benefits in Palestine resulting from the work done at the university in hygiene, bacteriology, zoology, physics, chemistry, biology, botany, geology and archeology.

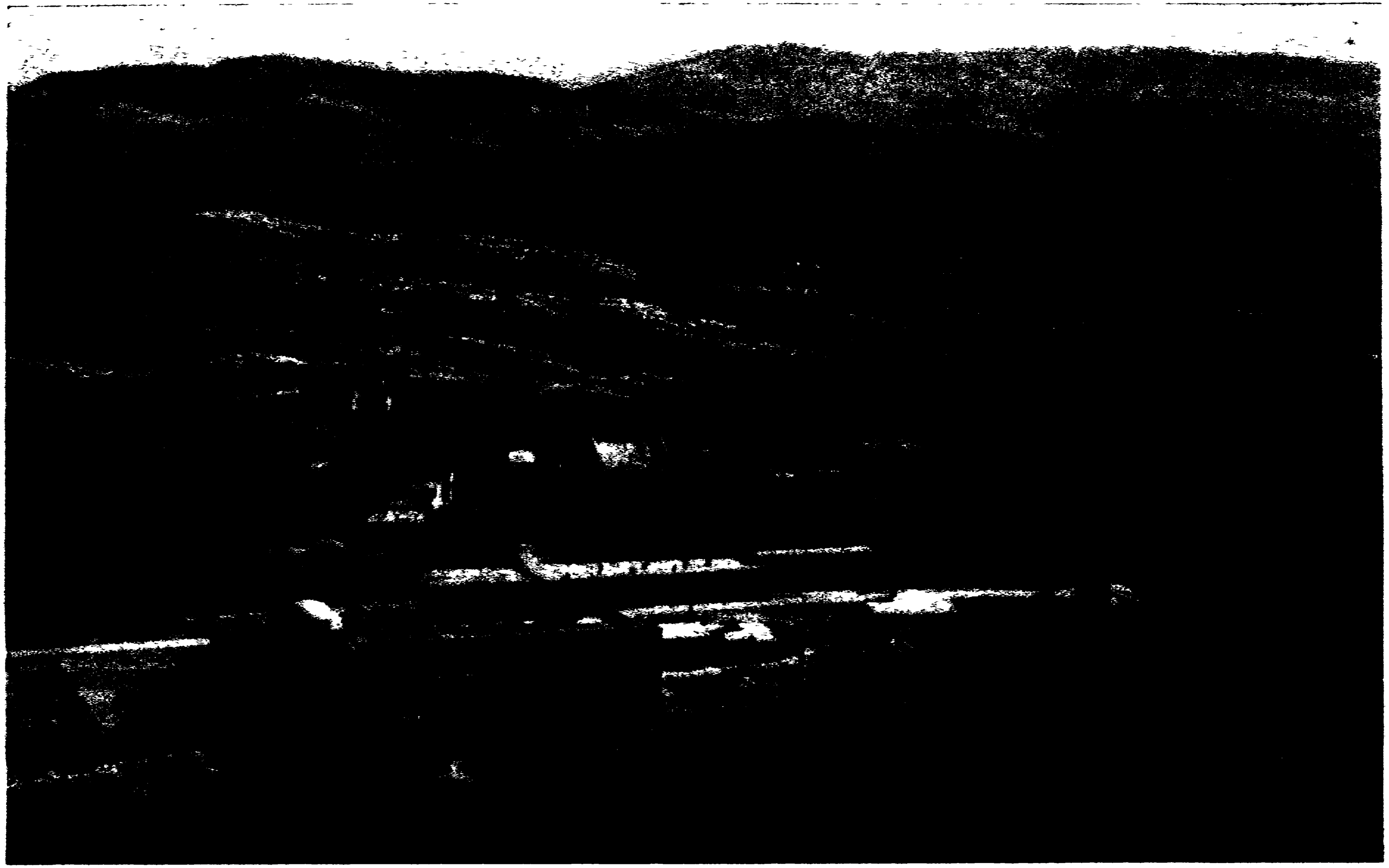
Researches conducted by the Institute of Chemistry in the field of soil formation and soil chemistry have supplied invaluable data on Palestinian phosphates, minerals, fermentation of tobacco and the utilization of alcohol, which have not only solved problems for industries already established there, but have opened up new fields for commercial enterprise.

For the biologist, Palestine offers a singularly valuable field of research. Here the flora and fauna of the Mediterranean region meet with those of the great desert belt that stretches from Morocco to Turkestan. In the Jordan Valley, tropical influences are to be found, while only a few hundred kilometers away are the snow-covered slopes of Mount Hermon in the Lebanon. With such sudden transitions, the influence of extreme factors on the distribution of living organisms can be investigated much better than at any other place.

The recently inaugurated Botanical Garden at the university is a reproduction of the ancient wood growths of the Palestinian hillsides in their virgin and pristine form. Much of the research work of the department of botany is also being concentrated in the study of plant physiology on the water metabolism of the plants.

The university contains the only Museum of Biblical Botany in existence, including the floral prototype of the Menorah (seven-branched candelabrum) and the Rose of Sharon, as well as many other plants mentioned in the Scriptures. Successful projects in afforestation, irrigation and the cultivation of new products are also to be credited to the department of botany.

The work of the department of hygiene and bacteriology, aided by the Malaria



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CORRIDOR IN EINSTEIN INSTITUTE OF PHYSICS AND MATHEMATICS
HEBREW UNIVERSITY IN JERUSALEM, PALESTINE, SHOWING BUST OF MAIMONIDES, MEDIEVAL JEWISH PHILOSOPHER.

Research Station, partially subsidized by the League of Nations Health Commission, and the cancer and radium institutes, the first of their kind in the Near East, has had considerable effect in improving the health conditions in that region.

Observations made by the Malaria Research Station, which resulted in successfully combatting the disease in the Near East, showed that the anopheline mosquitoes behaved differently during the prehibernating season from the active breeding period in the spring and early summer. During the former time the insects disperse over large areas, from twelve to fourteen kilometers from their breeding place. It was also discovered that, contrary to accepted belief, anopheline mosquitoes feed in the open on people or animals sleeping out-of-doors near their habitats. Children below the age of four to six were discovered to develop no immunity to malaria infection even after repeated attacks, reinfection occurring frequently immediately after a cure.

Considerable progress has been made by the department of bacteriology in ascertaining the relation of climate to susceptibility to disease. High temperature, associated with a high relative humidity, plus excessive exposure to solar radiation, increases host susceptibility to typhoid infection. It was also found that at high temperature there is a higher Vitamin B requirement, and that with an insufficient Vitamin B intake, the high-fat-containing diets, common in temperate countries, are distinctly harmful in tropical and subtropical climates. These observations have led to the successful treatment, with proper nutrition, of infantile toxicosis prevalent among certain classes of children during the hot season.

The department of parasitology, under the direction of Dr. Saul Adler, whose

A LABORATORY CLASS IN BOTANY AT THE HEBREW UNIVERSITY IN PALESTINE.

researches won him the Chalmers Medal, the highest award of the Royal Society of England, has made considerable progress in alleviating cattle diseases by its researches in kala-azar, or sand-fly fever, and theileriosis, or East Coast cattle fever. Great benefits have been derived agriculturally in Palestine by the researches of the department of zoology in migratory locusts, as well as in methods of combatting some of the citrus insects.

Exploration of uninhabited regions in the southern and eastern parts of Palestine has been made by the geology department at the university with the purpose of discovering new territories for settlement. Construction activities in Palestine have also been considerably aided by the work of the Materials Testing Laboratory in ascertaining the type of construction material suitable for the climate.

With Palestine and neighboring regions a rich source for archeologists, tremendous progress has been made in archeological discoveries conducted by the university in cooperation with Harvard University and similar institutions. Ancient Jewish tombs and synagogues found by the university's archeologists have done much to fill in wide historical gaps, while the recent discoveries of the Lachish potsherds, traced back to the time of Jeremiah, have done much to confirm the historical accuracy of the Bible.

According to plans of the university for the next few years, an expansion of scientific activities is expected. The plans include the founding of a School of Sub-Tropical Medicine, with the erection of the Hadassah-University Hospital and the Medical Building, already under way. Other projects of great scientific significance are the establishment of a meteorological station, an engineering school, an agricultural college, an institute of natural and exact sciences and a museum of natural history.

A. F.

THE SCIENTIFIC MONTHLY

DECEMBER, 1937

OUR SAMPLE OF THE UNIVERSE

By Dr. EDWIN P. HUBBLE
ASTRONOMER, MT. WILSON OBSERVATORY

The Observable Region of Space

Our sample of the universe is the region of space that can be explored with existing telescopes. The observable region is defined by the largest telescope available, and, in our generation, that telescope has been the 100-inch reflector at the Mount Wilson Observatory of the Carnegie Institution of Washington.

It was the 100-inch reflector which pushed out beyond the boundaries of our own stellar system and found other stellar systems—the nebulae—which are the true inhabitants of space. The nebulae had long been observed as mysterious patches of light strewn among the stars. Now, with their nature established, they are recognized as gigantic beacons scattered through the depths of space. The nearer nebulae appear large and bright; the more remote nebulae, small and faint. They can be followed on and on until they dwindle to mere specks and then vanish completely.

The vanishing point—the last horizon—is immensely distant. On photographs with the 100-inch, nebulae can still be recognized when they appear about two million times fainter than the faintest star that can be seen with the naked eye. Yet these specks are the images of great stellar systems which average about 200 million times as bright as the sun. In order to appear so faint, they must be so distant that light travels for 500 million years to make the journey. Thus the observable region of space, as defined with the 100-inch reflector, is a sphere about 1,000 million light years in diameter. This sphere, it is estimated, contains about 100 million nebulae, each a stellar system comparable with our own system of the Milky Way.

The nebulae are scattered irregularly; there are isolated nebulae, groups and, occasionally, great compact clusters. Nevertheless, a preliminary reconnaissance has shown that, when very large volumes of space are compared, the irregularities tend to average out, and the distribution approaches uniformity. On the grand scale, the observable region of space is very much the same everywhere and in all directions.

The preliminary evidence of uniformity suggested that the observable region might possibly represent a fair sample of the universe at large. As long as our knowledge was confined within our own stellar system, the possibility did not exist. The universe, we knew, was not filled with stars. But now the explorations have penetrated beyond the Milky Way. Our sample of the universe has been suddenly magnified a million, million fold. We study a vast region of space populated with stellar systems, and the region appears to be homogeneous. There is not the slightest evidence of a super-system of nebulae isolated in a larger world. It is quite possible that any other large region of the universe, selected at random, would be rather similar to the particular region we explore with our telescopes.

Of course, we can not be certain. We do not know what lies beyond the limits of our telescopes. But the possibility exists, and it offers a welcome relief from sheer speculation. It justifies an attempt to infer the nature of the universe from the observed characteristics of the sample available for inspection. This attempt has been called the observational approach to cosmology.

THE PROBLEM OF COSMOLOGY

The reconnaissance had revealed two general features of the sample, namely, the roughly uniform distribution of the nebulae, and the roughly linear law of red-shifts in nebular spectra. These two characteristics, together with the general laws of nature, were all the information we had to guide the investigation of the structure of the universe. Therefore, the first step in the venture was to follow the reconnaissance with accurate surveys extending out to the practical limits of reliable measures with the 100-inch reflector. The limits are somewhat less than the extreme range of the telescope, but the outermost fringe had to be sacrificed in the interests of precision. The surveys added no new features to those already available, but they formulated the latter in precise numerical terms.

A careful examination of the results has led to two conclusions. In the first place, the observational data alone are not yet sufficient to completely describe the universe as a whole. Many possible types are ruled out, but a unique structure is not determined. In the second place, the law of red-shifts proves to be a vital clew, but the origin of red-shifts, an essential element in the interpretation of the clew, is still an open question.

The negative conclusions were inevitable. It was too much to hope that the structure of the universe would be revealed at this early stage in the development of scientific inquiry. Nevertheless, the first empirical attack has been remarkably successful in clearing the ground and orienting the problem. It might be said that a choice is presented, as once before in the days of Copernicus, between a very small finite universe and a universe indefinitely large plus a new principle of nature.

ALTERNATIVE INTERPRETATIONS OF RED-SHIFTS

The new surveys permit us to reformulate the general features of our sample: the large scale distribution of nebulae is strictly uniform and the law of red-shifts is strictly linear, within the uncertainties of the investigations. The uncertainties are small but even so the greater part arises from the underlying uncertainty in the interpretation of the red-shifts. For this reason, the discussion of our sample will be introduced by an account of the appearance and behavior of red-shifts in nebular spectra.

Light from the nebulae is very similar to sunlight, and is a mixture of many different colors. With a prism, these colors can be spread out into an ordered sequence known as a spectrum. The rainbow, of course, is a typical example. A careful examination of the spectrum, either of the sun or of a nebula, indicates that certain colors are missing—that the sequence is interrupted by gaps or dark lines. The gaps represent colors that are absorbed by gases in the atmospheres of the sun or of the stars in the nebula. The pattern of dark lines identifies the actual gases—for instance, calcium vapor, iron vapor, hydrogen—and the precise normal positions of the lines are well known from measures in the laboratory.

In the sun, and the stars of our own

system, the lines appear about in their expected normal positions. In the nebulae, however, the lines are found out of place—more or less to the red side of their normal positions. These displacements are the red-shifts. They are conspicuous features in the spectra of all nebulae except a very few of our nearest neighbors. The amount of the displacement—the size of the red-shift—is found to be proportional to the distance of the nebula in which it is observed. The proportionality—the linear relation between red-shifts and distance—is known as the law of red-shifts. It is evidently an important clew to the nature of the universe, provided the clew can be correctly interpreted.

Actually, the interpretation of red-shifts is of fundamental importance, and

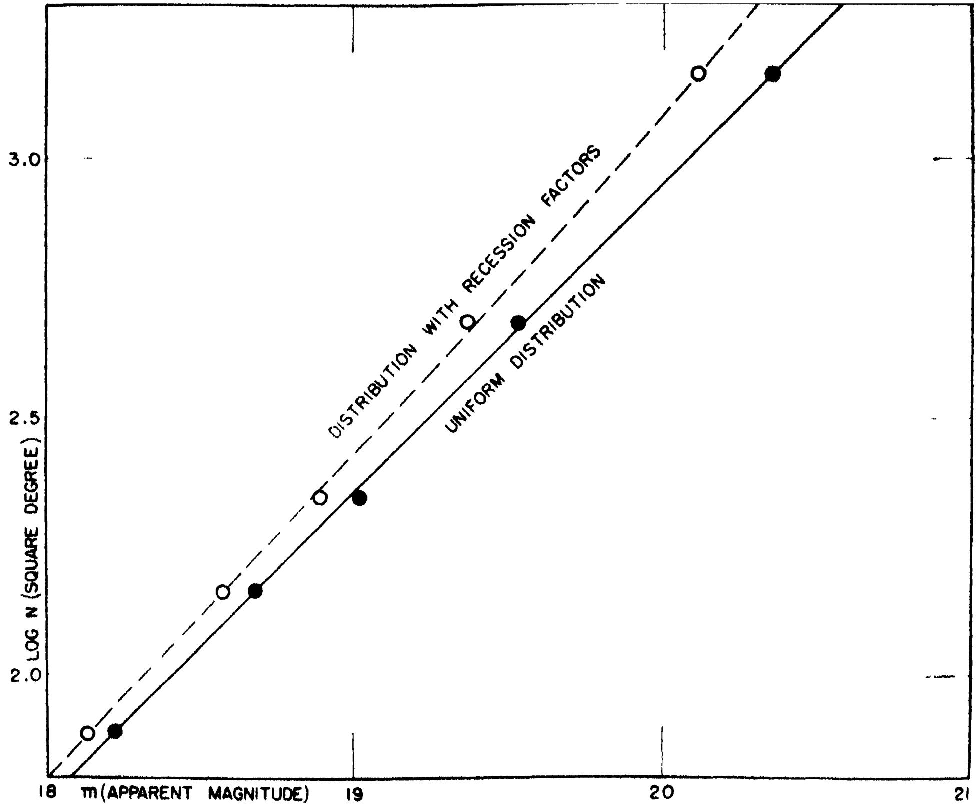

FIG. 1. DISTRIBUTION OF NEBULAE ON ALTERNATIVE INTERPRETATIONS OF RED SHIFTS

Each point represents the average number of nebulae per square degree, N, that are brighter than a particular limit of apparent faintness, *m*. Since *m* is a measure of distance, the curves represent the relation between numbers of nebulae and the volumes of space through which they are distributed. If red-shifts are not velocity-shifts (if the universe is not sensibly expanding) the numbers of nebulae increase directly with the volumes of space, and, consequently, the distribution is uniform. This result is indicated by the slope of the full line through the black discs. If red-shifts are velocity-shifts (if the universe is rapidly expanding), the additional corrections to *m*, demanded by the recession of the nebulae, leads to the distribution-curve represented by the broken line through the open circles. The curve implies that the density of the distribution increases systematically in all directions, leaving the observer in a favored position. Such an unwelcomed situation may be avoided by introducing sufficient spatial curvature to restore homogeneity. The required curvature implies that the universe, if it is expanding, is closed (finite but boundless) and quite small.

for two reasons. In the first place, red-shifts alter the apparent faintness of nebulae by amounts which vary with the interpretation. Since apparent faintness is the only general measure of nebular distance now available, we must know the proper corrections for red-shifts before we can construct an accurate map of the observable region. In the second place, red-shifts have been incorporated in the current theory of an expanding universe, and they furnish our only present means of testing the validity of the theory. Therefore, we must consider the phenomena of red-shifts in some detail.

The real nature of light is still uncertain; for many purposes, it may be treated in either of two ways, both of which lead to the same conclusions. We may picture light as traveling either in waves or in bullet-like parcels of energy called quanta. The waves have different wave-lengths, which are recognized by the human eye as different colors. Long waves are red and short waves are blue. Position in the ordered sequence of a spectrum is roughly indicated by color, and accurately indicated by wave-length. A red-shift implies an increase in the wave-lengths of all the light waves coming from a nebula.

On the other theory, we may speak of light quanta which carry different amounts of energy. To each wave of a particular wave-length, there corresponds a quantum with a particular energy content. The relation between waves and quanta is neatly expressed by the very fundamental relation, energy × wave-length = constant, or, in the usual short-hand notation, $E \cdot \lambda = C$. Thus the phenomena of red-shifts—the displacement of dark, absorption lines in nebular spectra—can be described either as an increase in the wave-lengths, λ, or as a decrease in the energy of the quanta, E. We may say that light-waves are lengthened in proportion to the distance of a nebula, or that light loses energy in proportion to the distance it has traveled.

Red-shifts are usually interpreted as the familiar velocity-shifts. If a luminous body is rapidly receding, the light-waves are evidently dragged out and lengthened. Consequently, all the lines in the spectrum of a receding light-source are displaced to the red of their normal positions, just as we find them in the spectra of nebulae.

Moreover, the amount of the displacement measures the velocity of recession. A shift amounting to a certain fraction of the normal wave-length represents a velocity which is that same fraction of the velocity of light. For instance, a shift of one per cent. of the normal wave-length represents a velocity of 1,860 miles per second; a shift of ten per cent., a velocity of 18,600 miles per second.

On this interpretation, the nebulae are receding from us in all directions, and their velocities are proportional to their distances. This strange phenomenon would appear to be an inherent feature of our sample; the universe itself would seem to be expanding. The velocities of recession increase at the rate of about 100 miles per second for each million light-years of distance, and ultimately they reach fantastic figures. The largest red-shift actually recorded represents a speed of 25,000 miles per second. If the increase continues at the same rate beyond the limits of the spectrograph, we may estimate that the faintest nebulae that can be photographed are receding at about 50,000 miles per second —more than a quarter of the velocity of light itself.

The assumption that red-shifts are velocity-shifts is the only known interpretation that is permissible. It is true that other ways are known by which red-shifts could be produced, but in each case additional effects would be introduced which should be conspicuous and actually

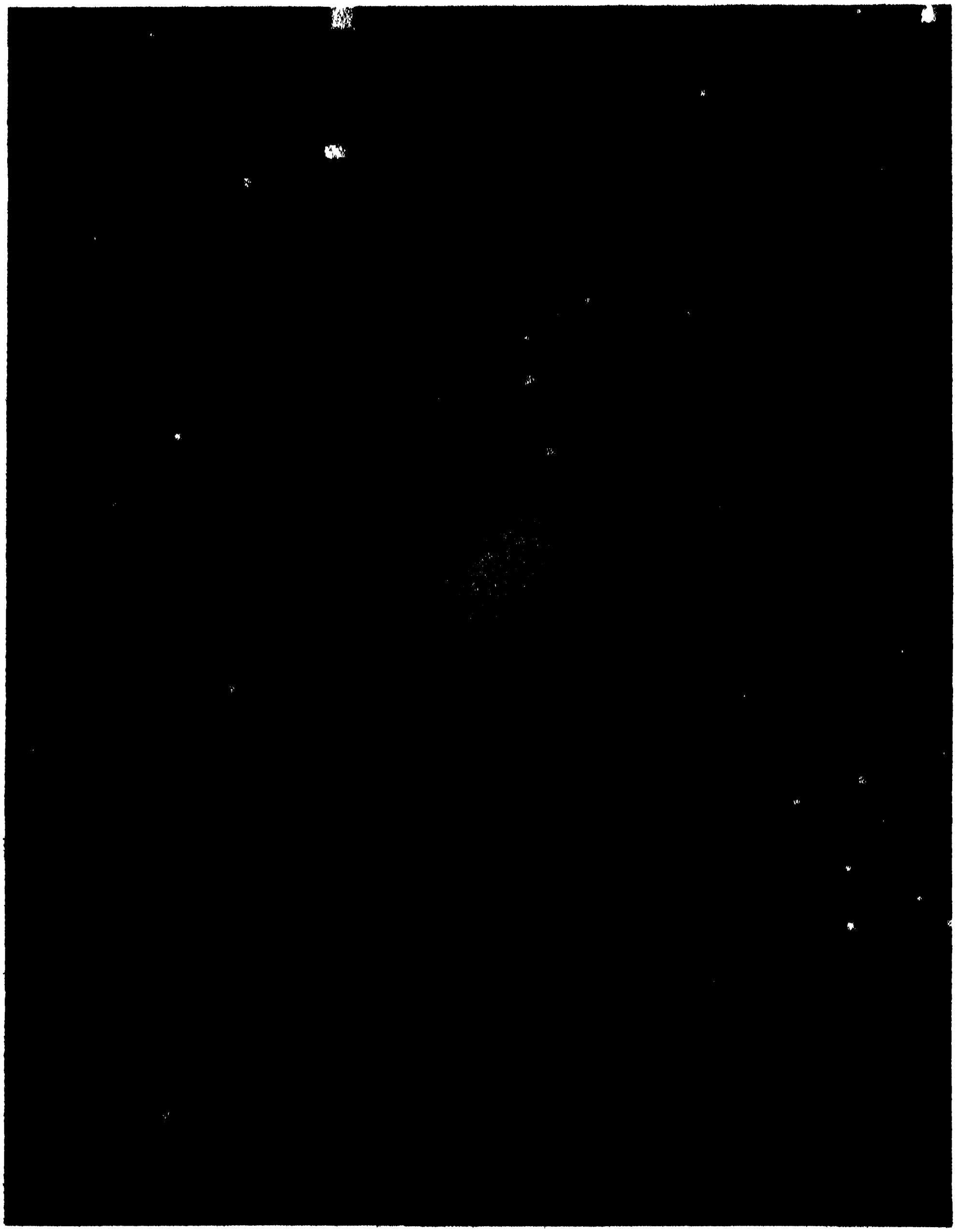

FIG. 2. MESSIER 81 IS A SPIRAL NEBULA IN THE VICINITY OF OUR OWN STELLAR SYSTEM.

It is so near (distance of the order of 2.5 million light years) that some of the brightest stars can be seen in the outer arms. These stars are similar to the brightest stars in our own system, and they indicate the distance of the spiral.

are not found. We may say with confidence that red-shifts are the familiar velocity-shifts or else they represent some hitherto unrecognized principle of nature.

Nevertheless, since it is improbable that our present knowledge of the principles of nature is complete, we may examine the question from a broader point of view. Red-shifts are evidently produced either in the nebulae, where the light originates, or in the intervening space through which the light travels to the observer. If the origin is in the nebulae, then, very probably, red-shifts are velocity-shifts, and the nebulae are receding. On the other hand, if the origin is in the intervening space, the nebulae are evidently not receding—at least they are not receding at an appreciable rate. We could completely describe the law of red-shifts by stating that light loses energy in proportion to the distance it travels through space. The description seems plausible, although we do not know how the energy would be lost.

METHOD OF TESTING THE INTERPRETATION OF RED-SHIFTS

Thus there are two possible interpretations, one of which involves motion and the other does not involve motion. Now, in principle, at least, the question of motion or no motion can be tested by direct observations. It is well known that a rapidly receding nebula would appear fainter than a stationary nebula at the same momentary distance. The recession, by thinning out the stream of quanta, would reduce their rate of arrival and, consequently, the apparent luminosity of the nebula.

The reduction factor is (1 + v/c), where v and c are the velocities of the nebula and of light. At ordinary velocities, the effect is negligible, but at the enormous velocities corresponding to the observed red-shifts, it becomes appreciable. For instance, at the limits of the deepest survey, the reduction in apparent brightness would be about 23 per cent.

If we had previous knowledge of the distances of nebulae, their apparent faintness would tell us at once whether or not the nebulae were receding. Unfortunately, we can not apply the test at the present time. Our only measure of great distances is the apparent faintness itself—the very quantity we wish to use for the test. Therefore, the direct investigations end in a vicious circle.

Nevertheless, it is possible to attack the problem indirectly. We may analyze the data from the surveys on the basis of distances calculated, first, on the assumption that nebulae are not receding, and, later, on the assumption that nebulae are receding. The two sets of results may then be compared with respect to their simplicity and their internal consistency The procedure, in effect, amounts to careful determinations of the law of red-shifts and the law of nebular distribution, using the alternative scales of distance.

THE LAW OF RED-SHIFTS

Let us start with the law of red-shifts, which is known to be approximately linear. If the nebulae are not receding, we find that, within the very small uncertainties of the investigations, the law is strictly linear—light loses energy exactly in proportion to the distance. As light travels through space, each million light years of the path has the same effect on its energy. In the absence of systematic variation, we must conclude that the observable region, large as it seems to us, is too small to furnish positive information concerning the universe as a whole.

Now let us assume that the nebulae are receding, that the universe itself is expanding. The nebulae appear fainter than can be accounted for by distance alone, and consequently, the distances, as previously estimated, must be corrected

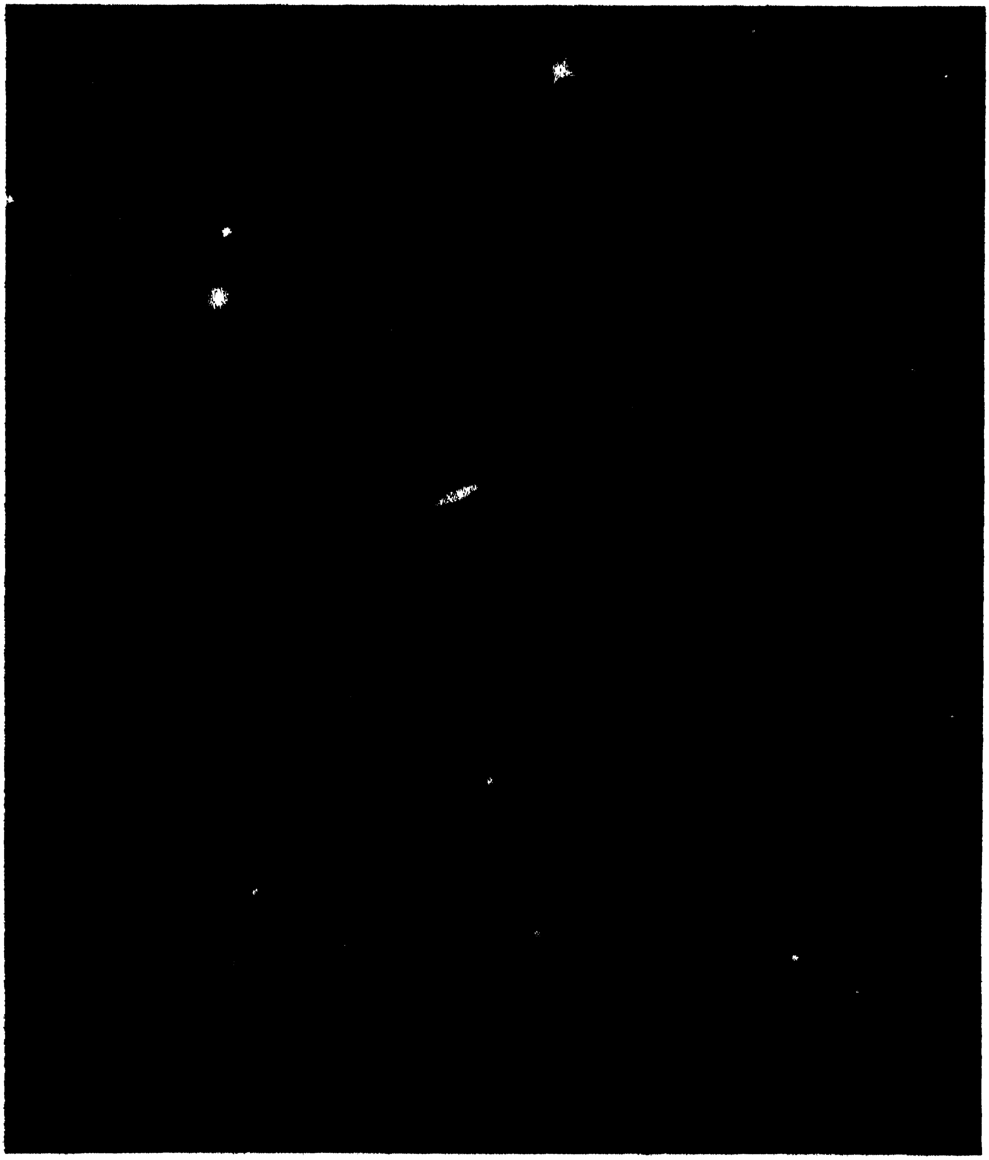

FIG. 3. VARIOUS TYPES OF NEBULAE

The four nebulae in the group, NGC 3185, 3187, 3190 and 3193, form a small sample collection of nebulae exhibiting a wide variety of types (possibly representing different stages in the evolutional sequence). The distance of the group is about seven million light years. The brightest nebula in the group is actually about 150 million times brighter than the sun, but is so remote that it appears about 270 times fainter than the faintest stars seen with the naked eye.

for the recession factor. Since the percentage corrections increase with distance, the revision is more than a mere uniform change in the scale. Therefore, the law of red-shifts, which was linear when the recession factor was omitted, can not be linear when the recession factor is introduced. The law necessarily departs from linearity. Red-shifts at a given distance are greater than those predicted by the linear law. In other words, the velocities of recession, or the rate of expansion of the universe, accelerates with distance.

This conclusion is important, for it means that we have found a general property of the observable region which changes systematically with distance. Our sample is now significant, for we can follow the trend of the change beyond the reach of our telescopes, and derive information concerning the universe at large. If the universe is expanding, we can state that it expands in a particular manner. Long ago, when the light we now observe left the distant nebulae, the rate of expansion was more rapid than it is to-day. For the last several hundred million years, at least, the rate of expansion has been slowing down.

The slowing down means that the age of the universe—the time interval since the expansion began—is less than previously supposed. The linear law pointed to an age of about 1,860 million years, and, into this relatively brief period of time, it was hoped to crowd a vast chronicle of events. Now, it is necessary to condense the history still further. How much, we can not say precisely—certainly to 1,500 million years, possibly to half that period. The significant fact is that the new data indicate a contraction of the period, rather than an expansion. Moreover, the maximum permissible time-interval of 1,500 million years is believed to be well within the life history of the earth; it is so short that we now explore with our telescopes at least a third of the entire range.

Thus the accurate formulation of the law of red-shifts presents a dilemma. The familiar interpretation of red-shifts as velocity-shifts leads to strange and dubious conclusions regarding the time-scale. The alternative interpretation that red-shifts do not measure actual motion leads to conclusions that appear simple and plausible.

THE DISTRIBUTION OF NEBULAE

The same sort of results are derived from the study of nebular distribution. Five independent surveys are now available, made with three different telescopes by two different observers. One of the surveys was made by Dr. Mayall, using the 36-inch reflector at the Lick Observatory; the other four were made at Mount Wilson, two with the 60-inch reflector and two with the 100-inch.

Each survey indicates the number of nebulae in the sky that are brighter than a certain accurately determined limit of apparent faintness—in other words, the number of nebulae within a certain specified distance from the observer. The limiting distances range from about 150 million light years for the shallowest survey to about 400 million light years for the deepest.

Thus we have available for study the numbers of nebulae in five successive volumes of space. If the distribution were uniform, the numbers of nebulae should be directly proportional to the volumes of space which they occupy. Preliminary studies had previously shown that the condition was approximately fulfilled. The more precise analysis involved the accurate determination of distances and, consequently, of volumes, on the alternative interpretations of red-shifts.

First, let us assume that red-shifts are not velocity shifts—that the universe is not expanding. Then, within the small

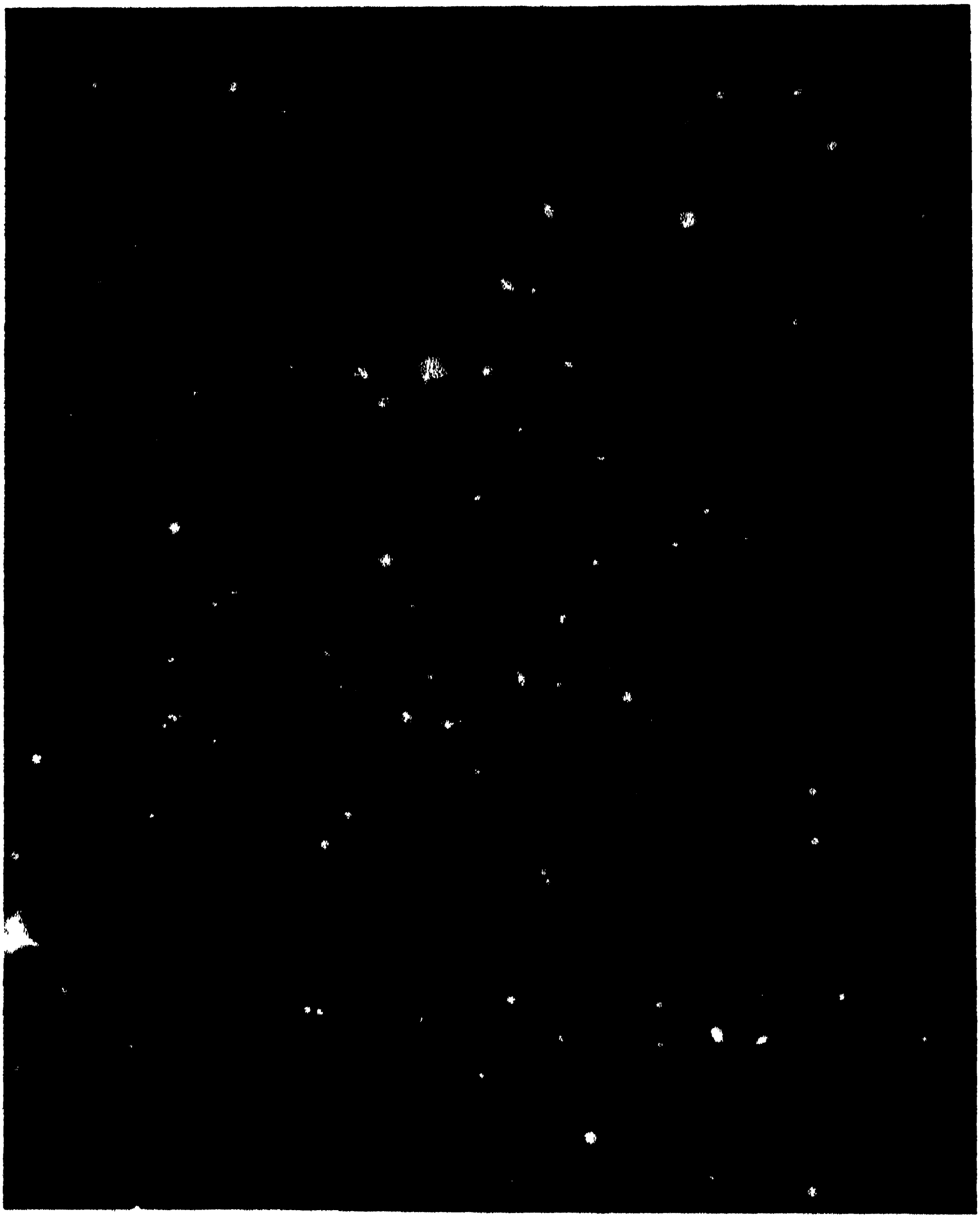

FIG. 4. A CLUSTER OF NEBULAE

The Corona Borealis cluster is a compact group of about 400 individual nebulae, at a distance of about 130 million light years from the earth. The photograph covers a central region in the cluster, about one tenth the area of the full moon, within which about 100 nebulae are found. The distance is so great that most of the structural details are lost. The nebulae appear as hazy patches, some elongated and some round, and the fainter ones are difficult to distinguish from stars.

uncertainties of the investigation, the numbers of nebulae are strictly proportional to the volumes of space. The distribution is uniform, the observable region is homogeneous, out to the limits of the deepest survey. There is no trace of a thinning out—no evidence of a super system of nebulae, isolated in a larger world. The observable region is an insignificant point, lost in the immensity of space. It is too small a sample to furnish positive information concerning the universe as whole.

The conclusion, you will notice, is precisely that derived from the formulation of the law of red-shifts. If the universe is not expanding, then it is vastly greater than the region that can be explored with existing telescopes. The consequence seems plausible, and even familiar.

But when we assume that red-shifts are velocity-shifts, that the universe is rapidly expanding, the picture seems to blur. Again, the recession factor alters the distances, and we may expect to find systematic departures from uniformity. However, the analysis is complicated by the fact that the light we now receive left the limits of the various surveys at widely different times in the past. While the light was traveling to us, the nebulae at the limits of the different surveys were receding, at different velocities, to still greater distances. In order to compare the surveys, it is necessary to reduce them all to a single epoch, and, as a matter of convenience, that epoch is selected as *now*, the time at which the surveys were made. Even then, the reductions are somewhat arbitrary, because they depend upon particular assumptions concerning the structure and behavior of the universe For this reason, we must venture a little into the shadowy realm of cosmological theory.

The Theory of an Expanding Universe

The outstanding theory describes "homogeneous expanding universes which obey the relativistic laws of gravitation." It is constructed from two major propositions The first is the underlying principle of general relativity which states that the geometry of space is determined by the contents of space. The second, the so-called cosmological principle, states that there is no favored position in the universe—that all observers, no matter where they may be located, will get the same general picture of the universe.

The cosmological principle is a sheer assumption, but it appeals to our sense of proportion. We mistrust the notion that our own stellar system has a unique position in the universe, just as our fathers eventually mistrusted the notion of a central earth Nevertheless, the assumption, although plausible, leads to some remarkable conclusions. For instance, if we see the nebulae receding in all directions from our position in space, then every other observer, no matter where he may be located, will see the nebulae receding in all directions from his position.

The kinds of universes which are consistent with the two propositions are demonstrated by intricate mathematical reasoning. Such universes are homogeneous, and they are unstable. In their normal states they are either contracting or expanding. The distribution of matter is uniform at any instant, but the average density changes systematically with time. Theory, in its present form, does not indicate the direction of change or the rate of change; our universe might be contracting or expanding, and at a rate that is rapid or imperceptible. However, the theoretical investigators, for the most part, seize upon the observed red-shifts, interpret them as velocity-shifts, and present them as visible evidence that the actual universe is now expanding rapidly.

The geometry of such a universe is not the familiar geometry of Euclid. It is another, more general, kind known as the geometry of Riemann, which involves the highly abstract conception of spatial curvature. The concept can not be visualized and it will not be discussed in detail. Two features, however, must be mentioned. In the first place, spatial curvature may be positive or negative. If positive, the universe is closed and finite (like the surface of a sphere); if negative, the universe is open and infinite. In the second place, the amount of curvature is measured by the radius of curvature. A small radius means highly curved space, while a large radius means small curvature. Flat, or Euclidean, space is the limiting case of zero curvature, and may be described by the statement that the radius of curvature is infinite

The various features—homogeneity, instability and spatial curvature—are necessary characteristics of the universe, provided we accept the relativity principle and the cosmological principle as initial assumptions. A universe is then fully described when we know the nature of the expansion or contraction, the nature of the curvature, and a third quantity, called the cosmological constant, which is associated with the contents of the universe.

The three characteristics might conceivably lie anywhere within wide ranges of values Therefore, the theory presents a long array of possible worlds. The problem for the observer, it seems, is to determine the three characteristics, and thereby identify among the possible worlds the actual universe which we inhabit. The law of red-shifts, when we interpret them as velocity-shifts, establishes the nature of the expansion, and, to this extent, has already restricted the array of possible worlds. The law of nebular distribution, as will appear, supplies the two remaining quantities.

THE DISTRIBUTION OF NEBULAE AND SPATIAL CURVATURE

Now we may return to the surveys. Let us assume that red-shifts are velocity-shifts and that we do inhabit a homogeneous, expanding universe which obeys the relativistic laws of gravitation. We correct the apparent luminosities for the recession factor, reduce the surveys to a single epoch, and then examine the distribution of nebulae. We find that the distribution is not uniform—the density increases outward, systematically in all directions. The observable region appears to be non-homogeneous, and we seem to occupy a special, favored position in the universe.

This situation, as has been mentioned, is as unwelcome as the earlier notion of a central earth. Moreover, it presents a discrepancy because the theoretical universe is homogeneous. For these reasons, we are forced to assume that the departures from uniformity are not real, and we search for some neglected factor which may compensate the apparent departures.

Now, in the whole of the theory, there is just one possible way of making the necessary compensation, namely, by means of spatial curvature. First we postulate rapid expansion, and it leads to discrepancies; then we postulate an additional effect in order to balance the discrepancies introduced by the first. The procedure seems artificial, but it offers the only possibility of preserving intact the theory of a homogeneous expanding universe. The curvature required to restore homogeneity is positive and very large. In other words, the radius of spatial curvature is positive and small—about 470 million light years, or slightly less than the penetrating power of the 100-inch reflector.

This result indicates that the universe, if it is expanding, is closed and finite. It has no boundaries in solid space, but the volume is finite, and, at the present time, is very small. With the 100-inch reflector, we now explore about a quarter of the entire universe. The conclusion seems strange and dubious, but it appears to be a necessary consequence of the theory of a homogeneous expanding universe

It might be mentioned, in parenthesis, that the radius of spatial curvature is a quantity that lies in a fourth or higher dimension. The unbounded universe of the theory has no radius in solid, three-dimensional space. The dim analogy, in two dimensions, is with the surface of a sphere, not with its volume. The radius of curvature of such a surface is, of course, the radius of the three-dimensional globe, but our analogy is restricted to the surface only. To an observer on the surface, all investigations would be restricted to the surface. He might imagine a circle, centered upon himself, whose radius corresponded with his radius of curvature as stretched over the surface of the sphere. This circle would enclose only a certain fraction of the total surface. Moreover, the line of sight, starting from the observer and proceeding along the surface, would never reach an end. The surface is closed and finite, but it is unbounded.

So, in the universe of theory, the line of sight, starting from the observer and advancing through solid space, never reaches a boundary. So likewise, the volume within a sphere whose radius is the radius of spatial curvature stretched through three-dimensional space, is but a certain fraction of the volume of the universe, namely, about one fourth.

The nature of the spatial curvature is the second of the three significant characteristics to be suggested by the observations. The third, and last, namely, the cosmological constant, can not be evaluated precisely, but upper and lower limits are readily calculated. The constant is associated with the contents of the universe and, while we know the nebulae fairly well, we do not know what lies between the nebulae Thus the contents of the universe are not completely known. However, the constant is not wholly independent of the curvature, and this fact, together with the evident proposition that internebular space can not be less than empty, furnishes curiously narrow limits between which the constant must lie It is definitely a positive quantity and it is rather small—the numerical value is of the order of 5×10^{-18} (years)$^{-2}$

POSSIBLE WORLDS

We may now identify the type of universe which we are supposed to inhabit, among the array of possible types that are offered by the theory. It is an "ever-expanding universe of the first kind"—in other words, a universe of the type associated with the name of Lemaitre and, later, of Eddington and others. It is a finite universe, quite young and small. Less than 1,500 million years ago, it started to expand from a relatively small, compact mass. At first, the expansion was rapid, but as time passed, the rate has steadily slowed down. To-day, we explore with our telescopes about a quarter of the entire volume and about a third or more of the past history The expansion will continue, and the universe will approach nearer and nearer to the de Sitter configuration—a universe so vast, so thinly populated, that each nebulae is completely isolated and lonely in the immensity of space.

The remarkable features of this universe are all introduced by the initial assumption that red-shifts are velocity-shifts which measure expansion. Otherwise, our sample is insignificant, a small homogeneous region of a universe which extends indefinitely beyond the range of our greatest telescope. The latter conception would probably be adopted as a matter of course were it not for the fact that, in such a universe, we do not now understand how red-shifts could be produced.

But if red-shifts are the familiar velocity-shifts, if the nebulae are receding, the scale of distance must be revised and distorted by the recession factor. The distortions necessarily imply that the previously uniform characteristics of the observable region must vary systematically with distance Our sample then becomes significant and indicates the nature of the universe as a whole.

However, the systematic variations are exact equivalents of the recession factor. The departures from a linear law of red-shifts, the departures from uniform distribution, the spatial curvature required to restore uniformity, are each one the recession factor in another form. The "ever-expanding universe of the first kind" follows directly from the interpretation of red-shifts as velocity-shifts—and, at the moment, we know of no other permissible interpretation.

Thus the study of our sample of the universe, with the greatest telescope available, presents a dilemma. One set of phenomena, namely, red-shifts, is not yet fully explained on the basis of direct observations. The familiar interpretation leads to a strange and dubious universe; the alternative possibility, which some might call a strange and dubious interpretation, leads to a simple and familiar conception of a universe so vast that it can not be described in its totality.

It is possible that theory may be revised to evade the difficulty. Otherwise the definitive solution of the problem will doubtless await the construction of still larger telescopes. Meanwhile it may be emphasized that the field has been opened, the problem has been formulated, and the possible solution reduced to a narrow range, largely by the contributions of one instrument, namely, the 100-inch reflector. The revelations of this telescope seem to force upon us a choice between a small, finite universe and a universe indefinitely large plus a new principle of nature.

THE PANAMA CANAL: SOME GEOGRAPHIC INFLUENCES

By Dr. W. O. BLANCHARD
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IN 1914, 400 years after Balboa crossed the Isthmus of Darien, the Panama Canal was opened to the world's shipping. For many years preceding its completion, extensive studies were made to determine what countries and routes would be affected, the volume and character of the probable traffic and the tolls which the Canal might be expected to yield. 1934 marked the completion of twenty years of operation of the waterway. It would seem an appropriate time to examine the record of its accomplishment and its promise of future performance.

At the outset we must recognize the fact that the entire period of operation has been an abnormal one in world industry and trade. Furthermore, the conditions prevailing have operated, in the main, to curtail the use of the waterway. The world war, the slides in the Canal, the post-war boom and the world-wide depression which followed, have all operated to disorganize shipping, and these influences have been naturally reflected in the Canal business. With these facts in mind, let us examine the twenty-year record of its contribution to the maritime world.

VOLUME OF TRAFFIC

In spite of the abnormal circumstances cited above, the waterway has made an impressive record in its service to ocean shipping. Thus, there have been passed, in the two decades of operation, approximately 77,500 commercial vessels carrying some 364,000,000 tons of cargo.

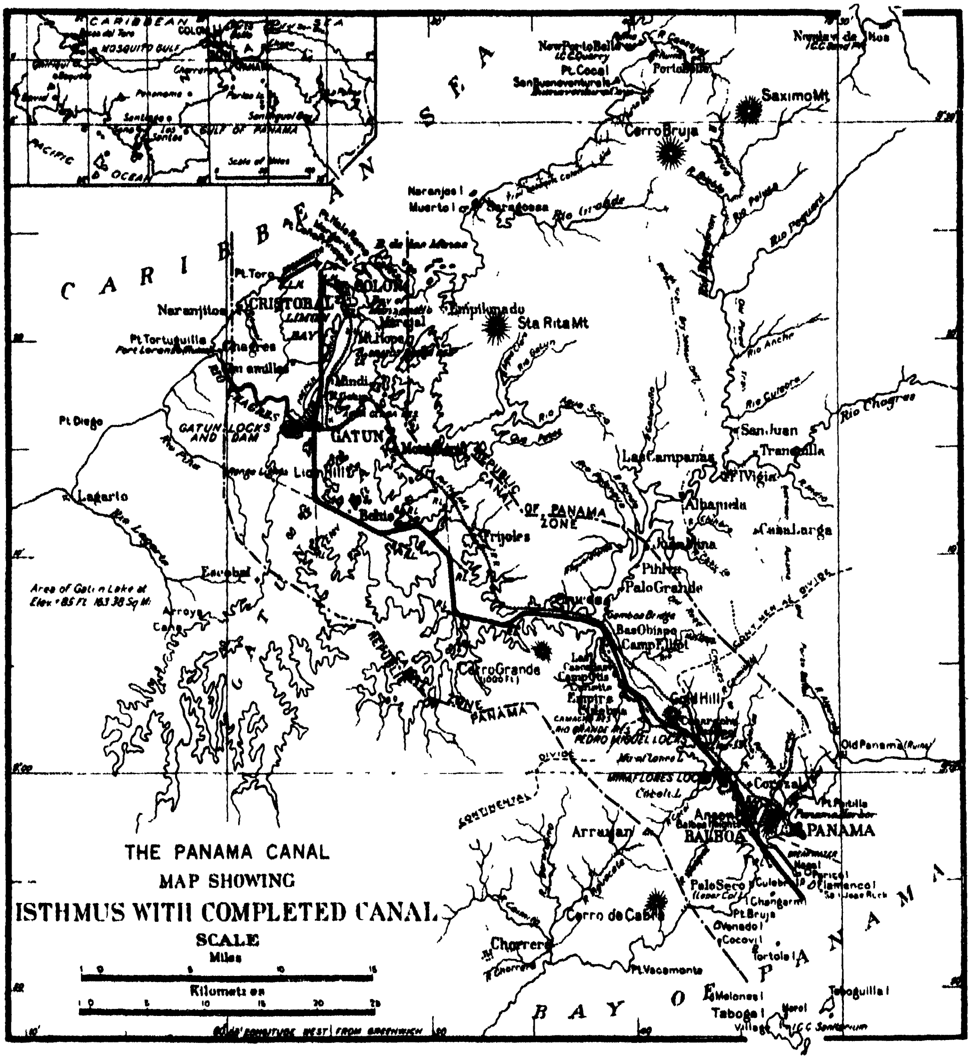
In addition to the *commercial* vessels, the waterway has been extensively used by vessels belonging to the governments of the United States, Colombia and Panama, as well as ships transited solely for repairs. In 1934, for example, over 500 of such toll-free passages were made. Most of these were by boats belonging to the American naval and military forces.

What the Canal would have accomplished had not the world war and other economic disturbances intervened can not, of course, be answered. However, it is certain that it would have been much more active than it has been. With all its fluctuations, the waterway has, with the exception of brief periods, increased its usefulness. During the second decade the number of transits was more than double those of the first ten years.

In Fig. 1, showing the cargo movement through the Canal, three distinct periods may be discerned. The first, covering the initial fifteen years, shows an almost uninterrupted annual increase in traffic. During the first half of the period the rate of growth was slow, but after some eight years, the California oil boom came on, followed by improving world trade and industrial conditions, so that the Canal business increased rapidly, reaching about 31,500,000 tons in 1929. The second period, 1929 to 1932, records a precipitous decline, a reflection of the world-wide depression. The third period, 1932 to 1934, represents a recovery of almost one half of the amount lost in the second period.

COMMODITIES MOVED

Because of the marked difference in the stage of economic development in the Atlantic and Pacific regions, there has always been a marked difference in both the character and amount of commodities



moving in opposite directions through the Canal. These differences are brought out in Fig. 2. In general, the Pacific countries contribute bulky products—lumber, wheat, petroleum, preserved fruits and fish from North America; nitrates and iron ores from South America; and wool from Australia. Silk and tea from the Orient constitute an exception to the general rule, since they are very compact and of relatively high value.

Commodities from the Atlantic borders, on the other hand, are, in general, manufactured or semi-manufactured goods of small bulk and large value. Iron and steel wares have long been the leading item.

As a result of this difference in the character of the goods, there has been an unfortunate lack of balance in cargo movement. For the whole period during which the Canal has functioned, the ratio of the tonnage of the Pacific to that of the Atlantic has been about 2 to 1 (see Fig. 3). The disparity seems to be growing greater. In 1934, it was about 3 to 1. For certain routes it was much worse. Thus European manufactures moving to Pacific America have filled only one seventh of the return cargo space. This puts a heavy burden upon shipments from these regions to Europe, and conversely, makes for low freight rates on west-bound vessels. As a result, Europe has become a keen competitor of the eastern United States in supplying manufactures to Pacific America. Even such bulky cheap commodities as cement and sand have been carried from Europe to the western United States

Classes of Vessels

According to the nationality of the vessels transiting the Canal, either British or American ships have led in every year thus far. From 1915 to 1918 British ships led; in the next sixteen years American vessels occupied first place. In 1935 the ratio of American transits to British was almost 2 to 1. The ratio based on cargo tonnage was about the same.

The preponderance of American vessels is to be expected in view of the relative importance of our cargo movement. This is especially true of the important intercoastal trade, which is limited by law to American vessels. Great Britain's high rank is due to her preeminent position in ocean shipping as well as to her interest in New Zealand, Australia and Canada.

What is the character of the average ocean-going commercial vessel transiting the Canal? The average of such ships, above 300 net tons, for the years 1933–35 inclusive, was a boat of approximately 5,500 net tons. It paid tolls of about $4,600 and carried 4,700 tons of cargo. If only laden boats were counted the average cargo tonnage would have been 5,600 tons.

With respect to motive power the Canal records show a constantly increasing proportion of oil burners as compared with the number using coal. For the fiscal year 1935, of the ocean-going commercial vessels recorded, about two thirds were steamers and about one third

CARGO TRAFFIC ON THE PANAMA AND SUEZ CANALS

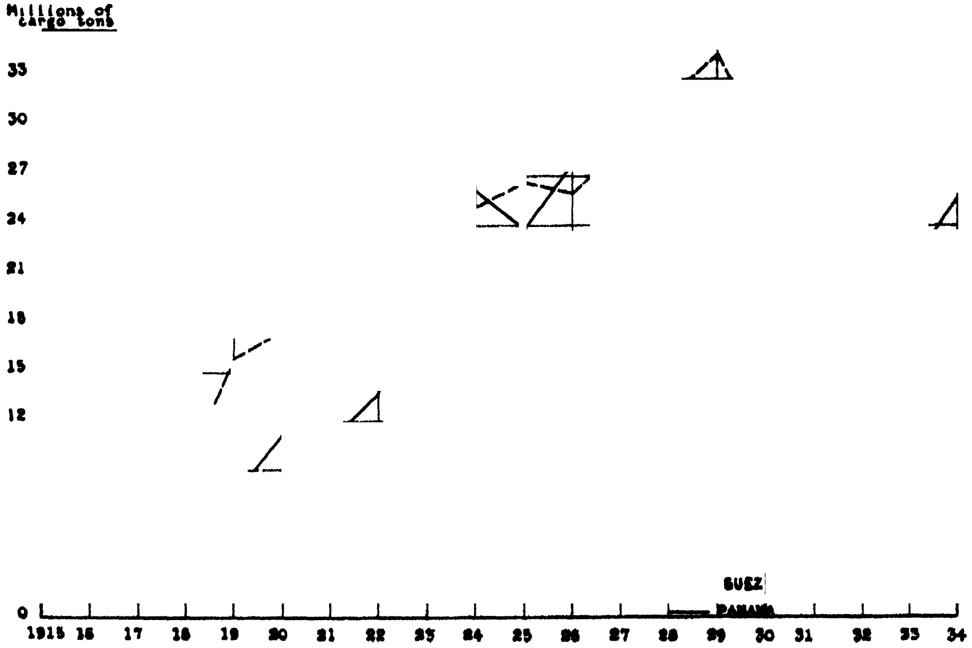
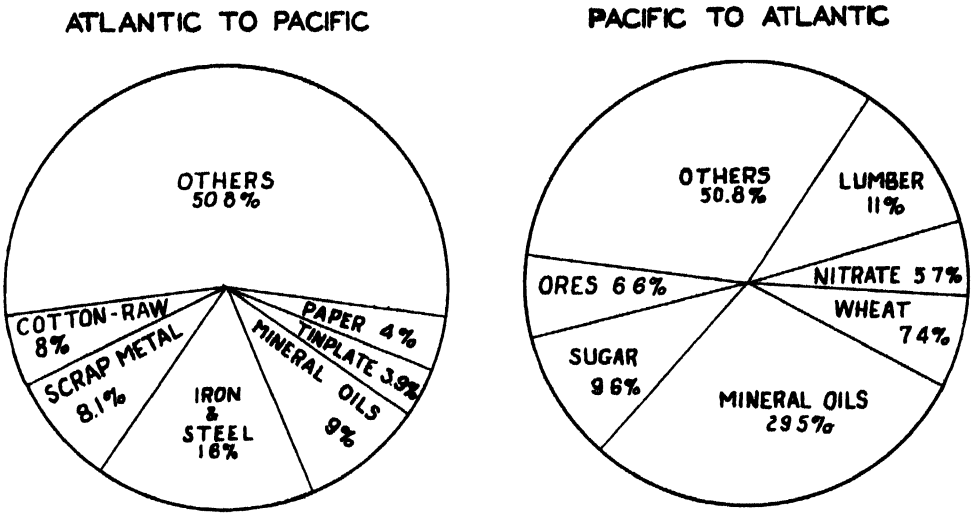


FIG. 1



PANAMA CANAL TRAFFIC 1934

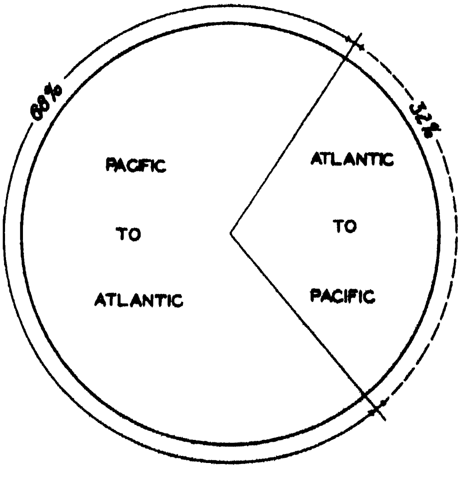
FIG. 2

were motor ships. Of the steamers, about three fourths burned oil and the remaining one fourth, coal. The abundance of oil and scarcity of coal in the Canal region and in the Pacific borderlands explains in part this trend toward oil as a motive power.

Aside from the general cargo vessels using the Canal, tankers have played an important rôle. These specialized carriers became important in 1923 when 913 transits of such boats were recorded. The peak movement occurred the next year with 1,704 passages. The number has gradually declined to 791 in 1935. Even in this latter year, however, oil made up almost one fifth of the total cargo passed.

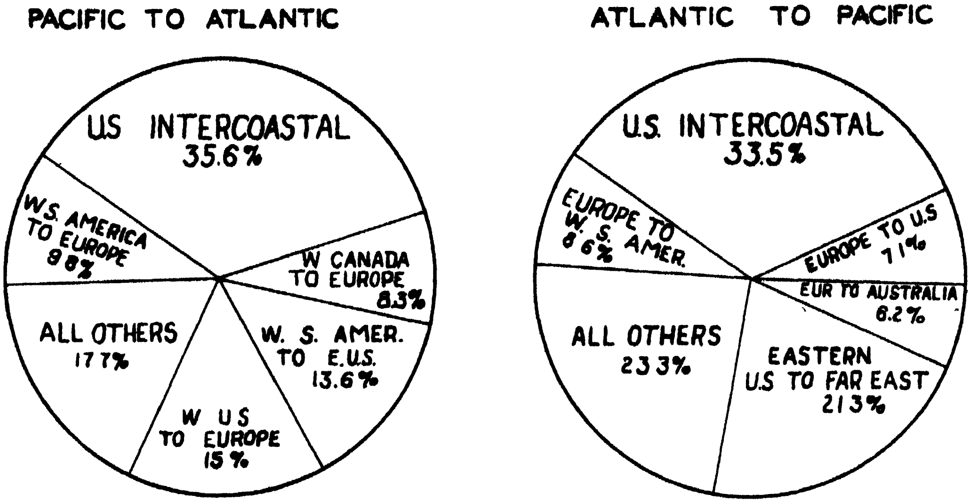
Routes of Greatest Importance

If we analyze the records of shipping through the Canal for the twenty years of its operation, it will be found that the great bulk of the traffic is concentrated into a very few definite routes. From what has been said above, it might be expected that those routes along which goods were being sent to or from the United States would be most important. And so they are. As shown in Fig. 4, of the movement through the Canal from Atlantic to Pacific, the United States intercoastal route accounts for 33½ per cent.; that from the United States to the Far East, about 21 3 per cent. Thus, these two make up over one half of the total in this direction.



TOTAL TONNAGE THROUGH PANAMA 1915 - 34

FIG. 3



PANAMA CANAL TRAFFIC 1914-34

FIG 4

Of the traffic transiting the waterway in the opposite direction, Fig. 4 shows the United States again to be far in the lead with 35.6 per cent.; the United States with Europe, 15 per cent.; and South America to Europe, 13.6 per cent. These three play the major rôle and together account for about two thirds of the total in this direction.

Regions Influenced by the Canal

Whence come all these cargoes? To what shores are they bound? Since the Canal joins the Atlantic and Pacific, its service should naturally be to the lands bordering these oceans. This is in general true, but, as shown in Fig. 4, there are notable exceptions. Thus the Atlantic coasts of both South America and Africa have their complementary trade areas in the North Atlantic; consequently the Canal is of little importance to them. The interests of the Far East and Australia likewise will be limited, for their trade with Europe will go mostly via Suez or Cape of Good Hope.

Among individual countries affected by the Canal, the United States occupies a unique position. American *domestic* commerce at present accounts for over one third of the total Canal business. American *foreign* commerce can be charged with another 40 per cent. This leaves only about one fourth of the Canal traffic moving between countries or parts of the same country other than the United States.

Next in importance among regions using the Canal is Europe, especially in its trade with the Pacific coast of both the Americas. It will be noted in Fig. 4 that of all the east-bound Canal traffic, that from the western United States to Europe ranks next to our intercoastal movement, although it is, to be sure, a poor second. As indicated elsewhere, these two routes from Europe to the two Americas suffer severely from the lack of balance on the two legs of the journey.

While the Canal brought the two coasts of the United States nearer, it may be noted that in so doing it placed the Mississippi Valley at a decided relative disadvantage. Industries, for example, in the Chicago district, which formerly supplied a market on the Pacific coast, now find themselves handicapped in competition with plants located on the Atlantic seaboard.[1]

The change has not been entirely to the advantage of the Pacific coast. Those ports have lost some of the transshipment business between the eastern United States and the Far East that used to go by rail to these Pacific ports, but now goes direct by the all-water route.

Other changes have occurred and still others will be found advantageous as normal conditions return and the readjustment is completed. It is interesting to note in this connection that raw silk, which formerly moved from the Far East to Seattle or San Francisco, there to be transshipped by rail to our eastern seaboard, is now practically all going via Panama.

INFLUENCE UPON TRANSCONTINENTAL RAILWAYS

The effect of the opening of the new water route on the United States railroads was far-reaching. In 1911, these railroads were estimated to have carried between five and six million tons between the borders of the Atlantic and Pacific That portion going via Magellan or the Panama or Tehuantepec railways was less than a million tons. By way of contrast, in the Canal's best year (1929) it moved in our intercoastal trade about twice the combined rail and water movement of 1911

Essentially all the water and probably

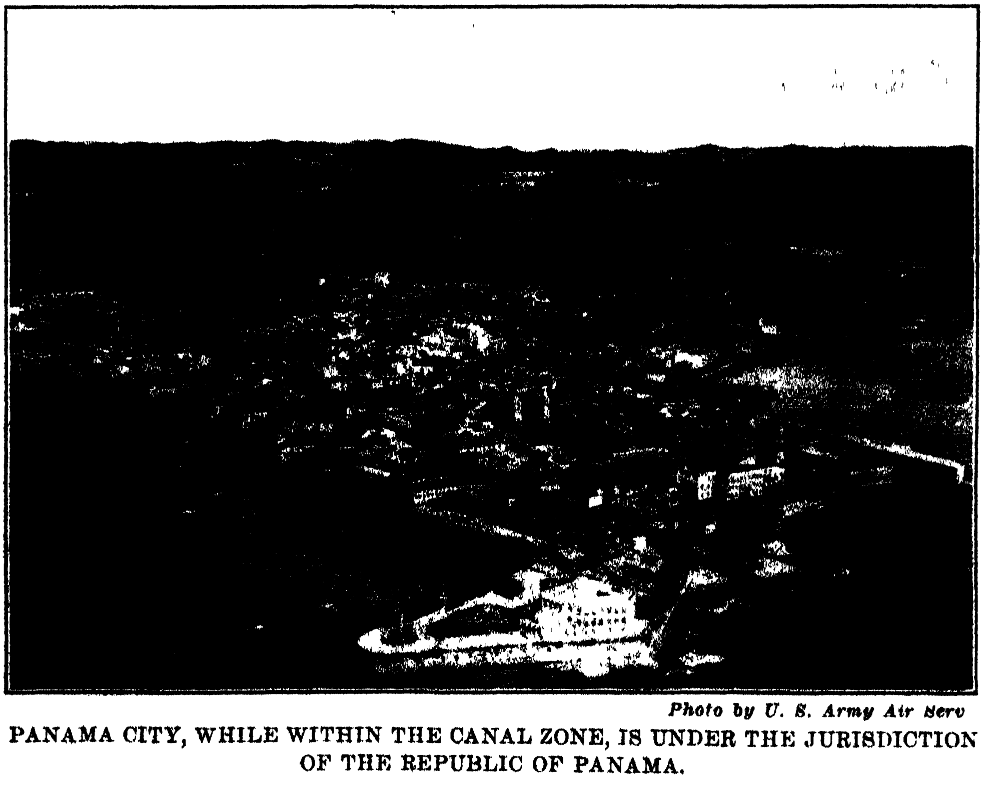


Photo by U. S. Army Air Serv

PANAMA CITY, WHILE WITHIN THE CANAL ZONE, IS UNDER THE JURISDICTION OF THE REPUBLIC OF PANAMA.

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[1] Since 1914 (the year of the opening of the Panama Canal) it is said that to move a ton of staples via the cheapest route, New York, which was then 1,904 cents from San Francisco, is now 1,280 cents away. Chicago, which was then 2,610 cents from San Francisco, is now 2,946 cents away. Chicago has moved away by 336 cents. New York has moved nearer by 224 cents. Furthermore, Chicago has moved 494 cents away from the Atlantic seaboard and from South America.

one half of the rail intercoastal movement of 1911 was diverted to the new waterway. This was a staggering loss for the railroads—a blow from which they have not yet fully recovered.

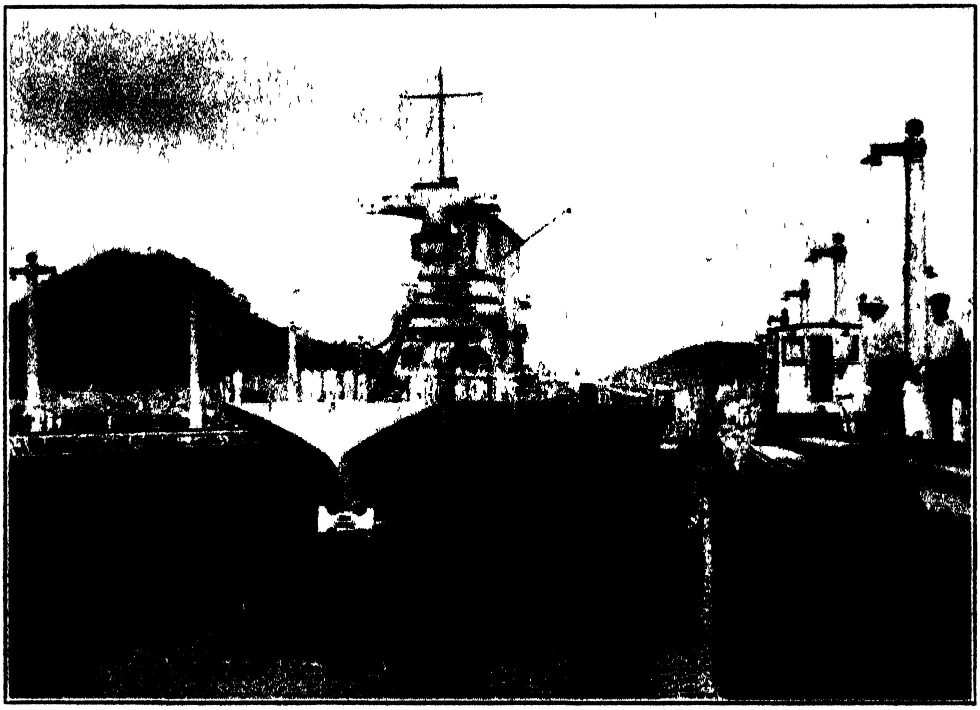
About one half of the Canal's intercoastal business is new, developed because the low rates attracted tonnage that never would have moved without this new attraction. This economical transportation was, of course, available only to the immediate hinterlands of the two coasts—say within two or three hundred miles of tidewater.

The savings on our intercoastal traffic have been estimated to average about $10 per ton. In addition, overland rail rates have been forced down by the potential alternative route, thus resulting in additional savings to the shippers still using the railroads. It seems possible that the total cost of the Canal could be justified on the basis of the savings on our coast-to-coast traffic alone.

THE CANAL AS A MILITARY ASSET

One of the major objects in constructing the Canal was to facilitate the movement of our military and naval forces between our coasts. It will be recalled that the voyage of the battleship *Oregon* around South America to join the Atlantic fleet during the Spanish-American war was a powerful factor in arousing American public opinion to the necessity of removing the Isthmus barrier.

In recognition of its military value, the Panama Canal Zone was made a military reservation. The Washington office of the Canal Zone is under the Secretary of War, and the governor reports to that cabinet official. Most of the gov-



U. S. AEROPLANE CARRIER "SARATOGA" IN PEDRO MIGUEL LOCK.
THE LOCKS WERE BUILT BEFORE SUCH BOATS WERE USED AND THIS ONE IS BARELY ABLE TO SQUEEZE THROUGH.

Photo by U S Army Air Serv

U. S. ARMY TRANSPORT ST. MIHIEL CROSSING GATUN LAKE.
NOTE THE FORESTED HILLS CHARACTERISTIC OF THE CANAL ZONE.

ernors have been chosen from the Army, and the Canal fortifications have been regarded as a part of our coast defenses. Army posts have been established there and a military population of some 8,000 men is quartered there. Both Canal entrances are fortified and there have been constructed flying fields, air service hangars and wireless stations.

The Canal was opened within a few months of the outbreak of the world war. Although it was not found necessary to move the fleet through the waterway during the war, the Canal was an important factor in the successful prosecution of the cause of the Allies. Huge quantities of supplies from the Pacific were sent through. Included in these cargoes were some three and a half million tons of Chilean nitrate for explosives. Allied vessels, both merchant and naval, found at the Canal terminals supplies of foodstuffs and fuel as well as repair facilities, hospitals and other services. Since the war, our fleet has on several occasions passed through the Canal without serious delay or mishap, showing conclusively its value as a military asset.

FUTURE OF THE CANAL

The present capacity of the Canal is estimated, on the basis of 7,500 net tons per lockage, at from 70,000,000 to 75,000,000 Panama Canal net tons annually. This is about three times the 1934 tonnage actually using the Canal. When necessity arises, it will be entirely feasible to expand the capacity by constructing a third flight of locks. This would enable the waterway to handle about five times the present traffic. Likewise it can always be turned into a sea level canal if it seems desirable. In general, it may be said that the facilities are now ample, and they can be expanded to care for any increase likely to develop within the next century.[2]

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[2] According to the engineers in charge it would even be feasible to fill the locks by pumping from the sea as a last resort.

Photo by U S Army Air Serv.

A NATIVE VILLAGE TYPICAL OF THOSE OF THE REPUBLIC OF PANAMA.

The Canal a Notable National Accomplishment

As an engineering accomplishment the Canal ranks among the foremost undertakings of man. In sanitation it represents one of the greatest triumphs of man over disease, with a health record comparable with that of many American cities. In its operation it has profoundly affected world shipping and quickened the commercial life of vast areas. It is a piece of work of which every American can be justly proud.

The story of a great torrential river made over into a navigable waterway, of a great mountain ridge grooved and bridged by a great artificial lake, of a pest hole transformed into a healthful dwelling place, of all this being accomplished without the least suspicion of graft or corruption—such an accomplishment is one of which any nation may well be proud. It may never pay in tolls the actual expenditure, but directly and indirectly it has been a highly profitable investment. In addition, it has been an impressive lesson for our Latin American neighbors—an example of what may be accomplished for peaceful intercourse among the nations.

FISHES AND RINGS

NOTES AND ILLUSTRATIONS OF VARIOUS FISHES WEARING RUBBER BANDS

By Dr. E. W. GUDGER

ASSOCIATE CURATOR OF FISHES, AMERICAN MUSEUM OF NATURAL HISTORY

To some of my readers my title will at once recall the stories of beauteous maidens, who, toying with their rings, dropped these from bridges or boats into the streams below Then followed weepings and wailings (and probably gnashings of teeth), which continued until some obliging fish, when caught nearby, would be found to have in mouth or "inwardness" the missing ring Restoration of this to the bereft maiden was always followed by smiles, happiness and serenity

Then there is the oft-repeated tale in the monastic legends of the Dark and Middle Ages of the wedded wife who loses her wedding ring, of the husband who notices its absence and becomes insanely jealous, and of the obliging fish which, with or without the intervention of some saint, retrieves the ring and heals the breach. Perhaps the recital of one of these stories may not be amiss. Thus it is reported of St. Kentigern that:

> A lady of good place in the country having lost her ring as she crossed the river Clyde, and her husband waxing jealous, as if she had bestowed the same on one of her lovers, she did bemean herself unto Kentigern, entreating his help for the safety of her honour; and that he, going to the river after he had used his devotion, willed one who was making [ready] to fish to bring the first [fish] that he caught, which was done. In the mouth of this fish he found the ring, and sending it to the lady, she was thereby freed of her husband's suspicion.

Thus both the fish and the saint did their good deed for the day and everything was lovely. Furthermore, as proof of the authenticity of this account, it is stated that "the see and the city of Glasgow [the scene of the Saint's labors, 514–601 A.D.] do both of them bear in their arms a fish with a ring in its mouth even unto this day."

It would be interesting to go further with these accounts, but they make "another story" which I hope possibly to write some other day. This article will deal with fishes *wearing* rings, and rings of but one kind—rubber. Other fishes wearing rings of other kinds will be dealt with later, *d. v*

I. BONY FISHES WEARING RUBBER BANDS

It is an interesting fact that in various parts of the world various ordinary bony fishes have been captured wearing rubber bands. My own collection of such is large and valuable. These will first be described, and next citations from the literature will be given. It seems worth while to bring all these interesting data together and thus effectually to establish the truth of this often doubted phenomenon.

A MACKEREL WITH A RUBBER BAND

Here is how it all came about so far as I am concerned. On August 1, 1927, a telephone message from the director said, "Would you mind coming up to my office?"; and I answered "I'm on my way." Wondering what I had or had not done, I walked into the office to be handed a small mackerel (*Scomber scombrus*) with a rubber band around it. "What do you think of it?" he queried. "Interesting specimen," I replied. Then he gave me the brief history of the fish and said, "I wish that you would see what you can make of it," and I retired.

The fish having been caught the previous day off Clinton, Connecticut, was in pretty "high" condition, so I brought it to my office and put it in alcohol in my tank of piscine curiosities, washed my hands and—being hard pressed with other work—promptly forgot it. About two weeks later, I saw the director, who asked about the fish. I answered that it was in alcohol to be rid of the bacteria and bad smell and to be hardened for handling. I next went on vacation and, after my return in late September, when I saw the director, he again asked about his fish. I spoke of my vacation and of other work crowding in, but he said with mock severity—"If you do not write up that fish, I'll have to give you a permanent vacation."—I described it.

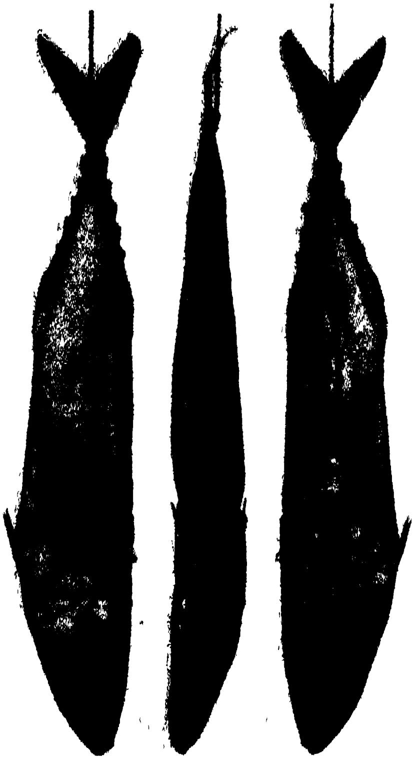


FIG. 1. A DORSAL AND TWO LATERAL VIEWS OF A MACKEREL WITH A RUBBER BAND.

THE TWO LATERAL VIEWS SHOW THAT THE FLAT BAND HAS CUT ITS WAY THROUGH THE ABDOMEN HALF THE DISTANCE TO THE UPPER SURFACE. THE TISSUES HAVE REGENERATED, CLOSING UP THE WOUND. THE CENTRAL FIGURE SHOWS THE TWO GROOVES CUT BY THE BAND ON THE BACK OF THE FISH.

As the photograph (Fig 1) shows, when the fish came to me the flat band had cut into the body from the belly side and the cut had healed up so that the band was rove clear through the body just below the level of the intestine Across the back it had cut two grooves. an anterior deep one, which was plainly the older, and a posterior and shallower one in an oblique position. The anterior one had formed scar-tissue in it, but the second (formed by the band as it grew softer and slacker) was still unhealed, as the figures show. Most interesting of all, however, is the faint scar on either side of the fish showing where the cut has healed up as the band moved higher and higher from the soft ventral surface. Here we have strong evidence of the great regenerative powers of the tissues in a fish—a cold-blooded vertebrate.

MORE MACKERELS WITH RUBBER BANDS

The description and three figures of this fish were published in April, 1928. The story aroused much interest and was given wide newspaper publicity, and for some time numerous like isolated items about rubber-banded mackerel appeared in the daily press.

All this brought in to me a great deal of corroboratory data, particularly from Boston, the center of the mackerel fishing industry in our waters. Mr. F. F. Dimick, the efficient secretary of the Boston Fish Bureau, sent me his Report for 1894 in which he had recorded at least 5 specimens of rubber-banded mackerel. Again in his Report for 1925, he noted that many such mackerel had come under his eye during the 20 years past.

Then Mr. R. A. Nesbit, of the U. S. Bureau of Fisheries, wrote me that, in making statistical studies of mackerel at the Boston Fish Pier, he had handled thousands of mackerel and had found the rubber-banded ones to be "surprisingly common."

This plethora of data was incorporated in another article on fishes with rubber bands. Publication of this in England led to the incoming of more data and specimens. Most of these, however, came from Boston, where Mr Nesbit had been succeeded at the Fish Pier by Mr. F. E. Firth, who as early as 1930 began to send me data and *specimens* of mackerel with rubber bands about their bodies. In fact, he has sent in so many specimens that I have had to beg him to desist for lack of space in my tank to hold them.

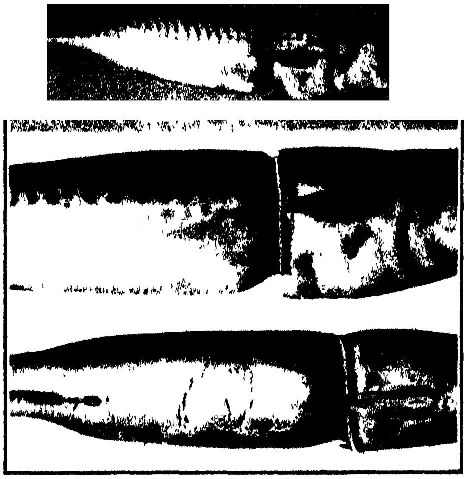
There are in this tank of piscine curiosities 10 undescribed mackerel with rubber bands. Nine of these were sent to me by Mr. Firth. These vary in total length from 13.5 inches to 18.25 inches. Five of them have the rubber bands or their marks around the "neck" of the fish—*i.e.*, across the back of the head, underneath the gill-covers on the sides, and across the "isthmus" or narrow part of the fish's throat where the two gill-covers come together, leaving an uncovered V. On the dorsum, in every case the rubber band has cut a furrow deeper than its own diameter and about three times as wide. In the isthmian region, in two cases there is no cutting, in the other three cutting has begun but has not proceeded far.

Sometimes in this region, the constriction of the band is so great as to nearly cut the head off. Such is specimen No. 10, a headless fish, sent to the museum by the Teddy Sea Food Company, of Fulton Market. It was caught near Block Island in June, 1934. I judge that the head was on this fish when it was rounded up in the net, but that it was broken off in handling the fish—"bailing" them out of the net and into the hold of the fishing vessel. This fish has had another band around the body about over the middle of the dorsal fin. This has left a distinct mark around the body, but has only barely cut through scales and the epidermis.

We now turn to the other mackerels sent in by Mr. Firth. Two have the band rove through the body something like what is seen in Fig. 1. In both cases there is a distinct scar, showing where the band has cut into the tissues of the belly wall. These have regenerated and thus the cut has healed. In the second and slightly better preserved fish the band has reached the level of the alimentary canal and has lifted this up, making an abrupt bend in it. The first one has two furrows on the back like that to be seen on the fish shown in Fig. 1, and the second has a much deeper single cut The third fish has had the ventral cut to heal up, leaving the band embedded, but on the dorsal surface the cut is over one fourth of an inch wide and in depth goes well down toward the backbone. This fish is in transition toward the next group.

Each of the two remaining fish has the body encircled by the band about over the middle of the dorsal fin. On the back each has a broad furrow cut down almost to the level of the backbone. On the ventral side each fish has been cut beyond repair nearly up to the level of the under side of the backbone. In this condition these fish grade right up to the headless specimen. But for the toughness of muscles and ligaments tying together the segments of the spinal column, these fishes would easily have been torn in two. Unfortunately they were poorly preserved here, and the viscera have so far gone to pieces that no study can be made of the effect of the band on these.

Of all the photographs on hand, only three will be reproduced (Fig. 2). The first shows in lateral view a whole mackerel which has around it just in front of the dorsal fin a round rubber band, which has made a deep groove. The second gives a "close up" of this lateral view, and the third shows the groove across the belly of the fish This groove is a wide one, evidently caused by the round band which has had sufficient resiliency to make a groove and yet has had sufficient play to make and keep the groove so wide that no healing has and possibly none can take place. Despite all, the fish seems reasonably fat and well fed.



—*Photographs by courtesy of Mr. F. E. Firth.*

FIG. 2. THREE VIEWS, TWO LATERAL AND ONE VENTRAL, OF A MACKEREL WITH A ROUND RUBBER BAND.

THIS ROUND BAND HAS MADE A DEEP U-SHAPED GROOVE ALL AROUND THE BODY OF THE FISH. THIS IS IN MARKED CONTRAST TO THE CUT MADE BY THE SMALLER FLAT BAND SEEN IN FIG. 1.

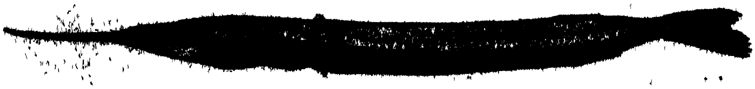
One wonders how these mackerel could have undergone such injuries without dying. But these cold-blooded animals seem to respond slowly to injury, especially if this comes slowly, and they have enormous recuperative and reconstructional powers. All of which facts are plainly attested by this series of mackerels afflicted with rubber bands.

These specimens are, however, but a fraction of the number of rubber-banded mackerel which have come under Mr. Firth's keen eye each mackerel-fishing season since he became interested. His letters are full of such records. For instance, late in August, 1930, he wrote that out of one "trip" of mackerel of only 1,500 pounds from Cape Cod, he had gotten 12 banded mackerel. These fish were small (about 13 inches long) and were probably about two years old. These bands were around the bodies just behind the heads and at least one was rove through the fish—*i. e.*, the band had cut into the body and the flesh had healed up.

RUBBER-BANDED BLUEFISH

The mackerel is a pelagic fish found in great schools at the surface of the sea miles away from land. The bluefish (*Pomatomus saltatrix*) is a member of a family of fishes not very distantly related to the mackerels. It too is a pelagic fish found off shore on the ocean's surface, and having much the same habits of life. With these facts before him, the reader may not be surprised to learn that it too is found with rubber band adornments.

My earliest account is from Mr. Nesbit, who writes that he had seen such a specimen in 1928. In 1933 Dr. J. S Gutsell was in charge of the station of the U. S. Bureau of Fisheries, at Beaufort, N. C. On January 4 of that year, he took a 10-inch bluefish "wearing a rubber band around the body just in front of the pectorals." This had cut into the fish a considerable extent both above and below. Later, Mr. Leonard Ross, of Washington, N. C., wrote me of a three-quarter-pound bluefish with a rubber band which had been brought in to the Washington Field Museum. His description reads as follows.



—*After Mr G P. Whitley, 1935*

FIG. 3. AN AUSTRALIAN GARFISH WITH A RUBBER RING.

THIS IS THE ONLY FISH WITH A RUBBER BAND THUS FAR REPORTED FROM THE SOUTHERN HEMISPHERE.

> This fish had a rubber band around its neck or body just behind its head. The band being much too tight had embedded itself into the flesh of the fish on the underside. The skin and scales have healed over. The scar was hardly noticeable, and the band could be slipped around backward or forward by merely pulling it through the hole. The fish was alive when caught and did not seem to suffer from its plight.

Here again we have evidence from an eye-witness that this fish was not seriously incommoded by a rubber band rove through its body.

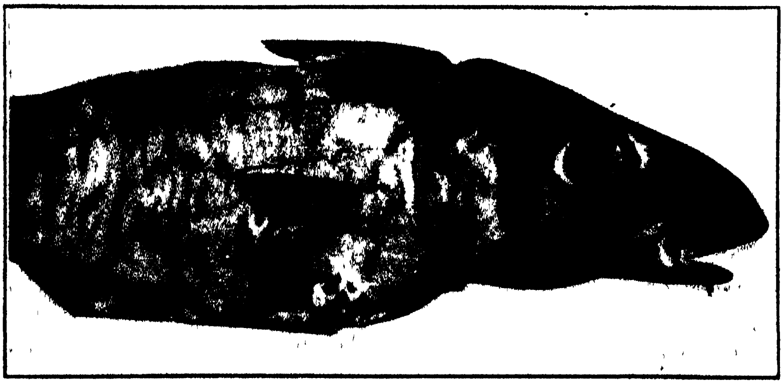
A Garfish with a Rubber Band

The garfishes all have long snouts and long slender bodies and are thus well fitted by nature for the acquiring of rubber bands in a fashion to be explained later.

Thus in August, 1934, in the far distant harbor of Sydney, Australia, a ten-inch ocean garfish with an encircling round rubber band was captured and was brought to the museum in Sydney. There it was recognized as the common Australian gar (*Reporamphus australis*), the first ringed fish ever reported from Australian waters. As Fig. 3 shows, its body was encircled by a small rubber ring, which had evidently been on the fish for some time, since it had become white and had worn a groove in the belly of the fish. This ringed fish was put on record by Mr. Gilbert P. Whitley, the learned ichthyologist of the Australian Museum.

Rubber-Banded Needlefishes

Professor Fernando de Buen, the Spanish ichthyologist, a valued correspondent in Madrid, has sent me an article recording in 1934 the occurrence of rubber bands on the Mediterranean needle-fish, ***Ramphistoma belone.*** This of itself is interesting, but one is amazed to read that between 350 and 400 such ringed fish were taken off the village of

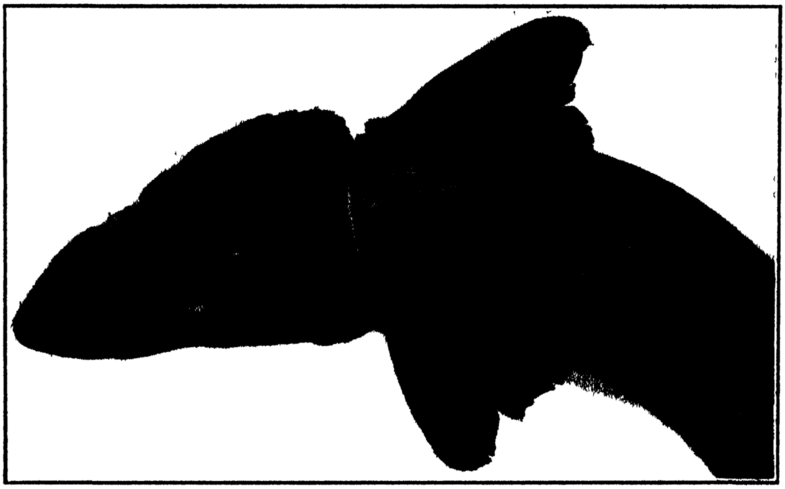


—*Photograph by courtesy of Mr. F. E. Firth.*

FIG. 4. A HADDOCK WITH A RUBBER BAND.

THIS IS THE ONLY CASE SO FAR REPORTED FOR A FISH OF THE COD FAMILY. THE RING HAS MADE A CONSIDERABLE GROOVE.

Es Sòtil on the coast of Minorca, the easternmost of the Balearic Isles. The prodigious number of these fish thus adorned is simply astounding. Many of them had the band around the middle of the body, a very few had the rings behind their ventral fins, but perhaps the largest number had the band over the opercular bones. Unfortunately Dr. de Buen published no figure of one of his fish.



—*Specimen by courtesy of Mr. F Specht*

FIG. 5. A DOGFISH WITH A RUBBER BAND AROUND ITS NECK.
THIS SPECIMEN FROM MT. DESERT ISLAND, MAINE, IS THE FIRST RUBBER BANDED DOGFISH EVER RECORDED.

A Rubber-Banded Haddock

Among other desiderata for this article, Mr. Firth has sent me photographs of a haddock (*Melanogrammus aeglefinus*) adorned like the first group of mackerel in the preceding section. This was taken in a trawl-net off Highland Light, Cape Cod, in water 35 or 40 fathoms deep in October, 1932. The specimen was not preserved. The band was around the head just back of the gill-covers, as Fig. 4 shows. It had apparently not afflicted the fish much, since it was taken alive. The photograph was unfortunately not made until after the fish had been dressed, hence it looks somewhat lanky—collapsed. This seems to be the only known case of a haddock with a band.

A Swordfish with a Rubber Band on its Sword

Even more remarkable are the accounts of a swordfish with a rubber band around its weapon. Mr. Nesbit writes that: "In the summer of 1926, a sword fish (*Xiphias gladius*) bearing a band on its sword was brought to the Boston Fish Pier. I examined the sword and personally removed the band from it. The band had cut a groove in the sword and had completely lost its elasticity." Mr. Dimick also writes that in 1926 or 1927 his attention was called to a swordfish in Boston with a rubber band around its sword. This was presumably the same specimen. Unfortunately no photograph was made.

A Sturgeon with a Band Around its Nose

Some years ago the North Carolina papers carried an interesting item about a two-foot sturgeon captured near Manteo, Dare County, in March. It was alleged that the snout of this fish about two inches in front of the eyes was encircled by a rubber band. This was embedded in the bony and other tissues to a depth of about one fourth of an inch. No photograph was made, nor was the fish preserved. The newspaper account states that the band was cut off and the fish set free. In passing it may be said that it hardly seems possible that fishermen and a local newspaper correspondent could ever have heard of a case of this kind, or that they could have fabricated this brief account.

How Fishes Acquire Rubber Bands

The easiest and the most commonly accepted explanation is that fishermen have caught mackerel and other fishes and for a fake or a hoax have put rubber bands on them and have turned them loose. In some cases this is probably true. I have no doubt that sometimes some fishermen have done and even to-day do such things But market fishermen on the mackerel grounds have other things to do besides slipping rubber bands on salable mackerel and putting them back into the sea.

A better explanation, in my judgment, is now to be offered. Rubber bands will float and they get into the seas in one of three ways. Thrown into the streets with other debris they are carried by rains through storm sewers into harbors. Or they are gathered by street cleaners along with other wastes, which are piled on scows, and these in turn are towed out to sea and dumped—as is the custom off New York. Or, in the third place, many such rubber bands are thrown overboard with other waste materials from steamships traversing the ocean.

Mackerel, bluefish, garfishes and needlefishes are all surface dwellers and surface feeders. These fishes nosing around will thrust their heads into the larger rubber bands which finally come to rest for the most part either just behind the head and in front of the pectoral fins, or when they slip over the pectorals they are arrested in front of the dorsal fin of the fishes. As the fishes grow larger the bands fit more tightly and cut grooves.

These bands, however, are found on small as well as on larger fishes, and for such I suggest this explanation. The young of mackerel, bluefish, garfish and needlefish, are found in harbors (unless the water is excessively polluted) swimming and seeking food around wharves. Here are likely to be found floating rubber bands of small as well as large size delivered by storm sewers The little fishes push snouts and heads into these, as noted above, and thus acquire their bands. As the fishes grow up, the bands cut grooves in their bodies, and, since in these cold-blooded fishes regeneration goes on at an astonishing rate, the groove heals up below as fast as it is cut above and the band comes to rest rove through the body of the fish.

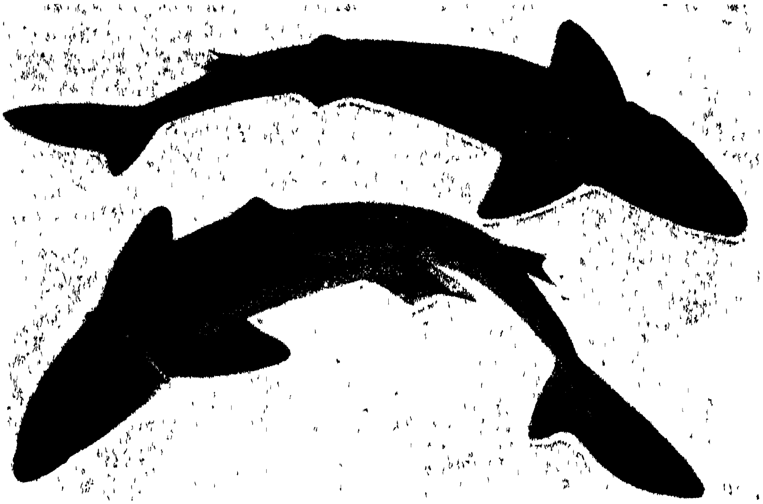
Dr. de Buen's rubber-banded fishes caught off a small island in the Mediterranean are difficult to explain. He thinks that the bands came from passing steamers. He does not state how great a stretch of time was covered in the collection of 350 to 400 needlefish thus adorned. One wishes for more data before attempting an explanation.

II. DOGFISH WEARING RUBBER BANDS AND A SHARK ATTIRED WITH AN AUTOMOBILE TIRE

Not only have various bony fishes wearing rubber bands been taken, but a number of dogfishes (small sharks) similarly adorned have been captured and photographed. And most remarkable of all, a fair-sized shark encircled with an automobile tire has also been photographed. These will now be figured and described.

A Dogfish with a Rubber Band

Early in July, 1931, Mr. F. Specht, the efficient collector of the Mt. Desert



—*Photographs by courtesy of Mr F E Firth.*

FIG. 6. TWO YOUNG DOGFISH (*SQUALUS ACANTHIAS*) WEARING RUBBER BANDS. THE UPPER FIGURE IS OF A DOGFISH TAKEN OFF CAPE ANN, MASS., IN NOVEMBER, 1932. THE SHARK PORTRAYED IN THE LOWER FIGURE WAS TAKEN OFF THE MOUTH OF CHESAPEAKE BAY IN FEBRUARY, 1933.

(Maine) Biological Laboratory, made a most interesting catch. When he hauled in his trawl in Frenchman's Bay off Salisbury Cove, among the other fishes in it was a dogfish (*Squalus acanthias*) with a rubber band about its head—the only known case at this time of a dogfish so adorned. Mr. Specht, knowing of my interest in such specimens, very kindly sent this fish to me. Fig. 5, made from a photograph, shows both fish and band.

The band had slipped over the head of the fish but could not get past the broad wing-like pectoral fins. On the ventral surface of the fish, it has barely made a mark on the tough skin. On the dorsum, where there was probably more pull, it has cut a shallow furrow in the shagreen and epidermis, but in the region of the hinder gill-slits and the unprotected gills it has done its work. The last pair of gills shows considerable damage, but the others are practically unhurt.

THREE MORE DOGFISH WITH RUBBER BANDS

Mr. Firth has sent me his notes on three rubber-banded dogfish (*Squalus acanthias*) which he has seen. Two (measuring approximately 21½ inches each) were taken in November, 1932, in mackerel nets off Cape Ann, Massachusetts Each of these had a rubber band around its head just anterior to the bases of the pectoral fins. The band had cut a groove in the flesh, as may be seen in the upper fish portrayed in Fig. 6, a photograph of one of the sharks noted above.

The third ringed dogfish of this species was a small fellow of only about 16 inches in total length. It was taken in February, 1933, in approximately 35 fathoms, about E. × S. of the Chesapeake Light Vessel, which lays about 12 miles out from the mouth of Chesapeake Bay. The lower fish shown in Fig. 6 is from a photograph of this small shark. Note the white spots so characteristic of the fish. Very clear also is the cut in the skin on the back of what may be called the neck of the fish.

Here, then, are presented data for four dogfish (of the same species) wearing rubber bands. So far as I can say these are the first records of such banded dogfish.

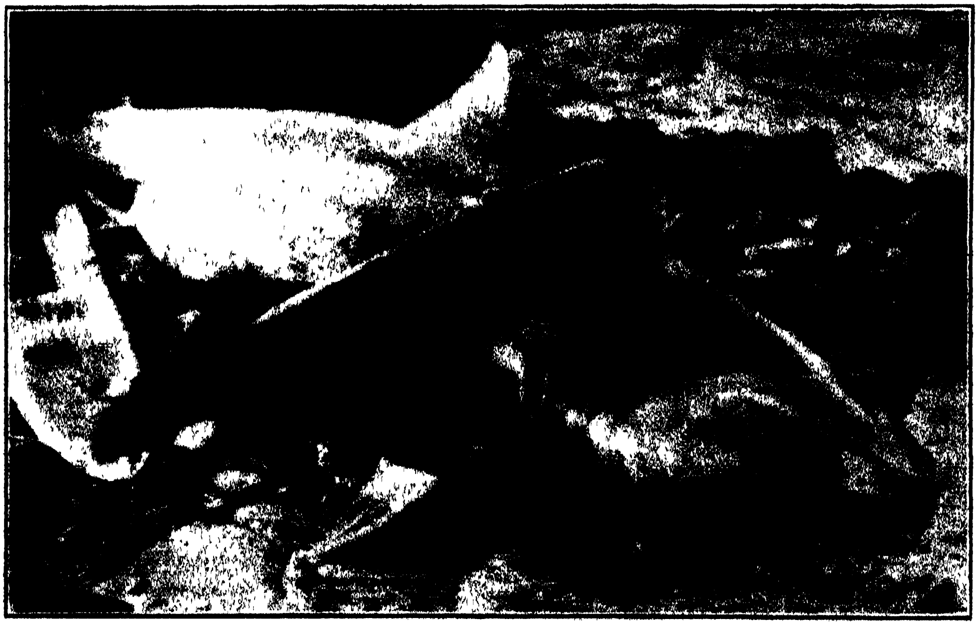
HOW DOGFISH BECOME BANDED

In the first part of this article, dealing with six kinds of bony fishes wearing rubber bands, I offered a tentative explanation for this phenomenon. The same explanation will apply to these small sharks. Street sweepings, debris and wastes of all kinds, including rubber bands, are loaded on scows, which are towed out to sea and dumped. These dogfish, probably when young, nosing around in the debris in search for something edible, thrust their heads into these bands. The bands were worked back onto the hinder gill-region, and later, as the dogfish grew up, the bands grew tighter and cut into the flesh.

A SHARK ATTIRED WITH AN AUTOMOBILE TIRE

As Fig. 7 shows, we are now come to the most extraordinary ringed fish of all cited in this article—a shark wearing an automobile tire. Its history is as follows.

In 1930, a valued correspondent of mine in Havana, Cuba, Dr. W. H. Hoffmann, of the Laboratorio Finlay, sent me a clipping from the *Diario de la Marina* of September 21, containing the illustration (Fig. 7) and a brief account of the capture of this shark in the Bay of Cojimar, a small fishing village about five miles east of Havana. On request, the editor of the *Diario* courteously sent me a copy of the photograph but could give no data beyond that contained in the lengthy caption published with the figure. However, the indefatigable perseverance of Dr. Hoffmann led him to make a trip to Cojimar and to hunt up the captors of the shark and ascertain the facts from them and from those who saw the fish when it was brought to shore.



—Photograph by courtesy of Diario de la Marina, Havana.

FIG. 7. A SHARK WITH AN AUTOMOBILE TIRE AROUND ITS BODY.
IT WAS CAPTURED IN COJIMAR BAY, EAST OF HAVANA, CUBA, IN 1930.

This shark was captured and brought in alive by two boys. They saw it out in the bay, fighting and lashing the water, and even trying to jump above the surface in its efforts to free itself. Seeing that the fish was helpless, the boys got a noose about it and thus ignominiously brought it to shore, where it was photographed. One observer told Dr. Hoffmann that the tire was so tight on the fish that one could see a ring which it had made in the flesh. This, however, is hardly confirmed by the photograph, wherein it appears that the tire has a certain amount of play. But the further statement of this man, that the tire was only removed by cutting the shark to pieces, is surely confirmed by Fig. 7.

How the Tire Was Acquired

It seems that, in Havana as in New York, street sweepings, garbage and all sorts of junk are loaded onto scows, which are towed out to sea and there dumped. Sharks are scavengers and they swarm at these dumping grounds to feed on the garbage. When a scowload of garbage was unloaded, we can see that our shark would dash forward and would nose about in it seeking what it could find to check its gnawing hunger. Just in front of the floating automobile tire, it smelled something edible. Clamping its big pectoral fins close to its sides to get them out of the way, I can see it as it drove straight ahead through the tire until its stiff unbendable dorsal fin fetched up against this. Fanning hard with its now free pectorals, it pushed forward hard to free itself from this strange encumbrance, which would not let go. Then came blind panic and it fought tire and sea as it was doing when the boys found it. Presuming that at least a day or two intervened between catastrophe and capture, we can understand that the shark, fighting the tire almost continually, unable to progress through the water and hence unable to procure food, would gradually grow weaker and weaker. And in the end, too weak to offer much resistance, it would suffer itself to be lassoed and towed to shore by the two boys.

When a brief note by Dr. Hoffmann and myself describing this fish was published, it attracted considerable attention and was abstracted and our figure reproduced in two journals of great circulation—*The Literary Digest* and *Time Magazine.* In this way it obtained wide publicity, and some interesting letters came in. One from a Texas man recounted how he and a friend had recently found on the coast of the Lone Star State an 8- or 9-foot shark stranded at low water in a shallow pool behind a sand bar. This shark they so easily mastered and killed by shooting that the letter writer suggested to me that "It would have been easy for us, had we had an automobile casing, to have put the same over the shark in the manner of that in your figure."

Having had considerable experience in fishing for and studying sharks at Beaufort, N. C., and at Key West and Dry Tortugas, Florida, I replied that I did not think it feasible even under the conditions under which they found their shark. For I know that, even the mildest mannered shark, when cornered, becomes as dangerous as a mad dog under similar conditions. In fact, in the light of my knowledge of and experience with sharks, I was ready unanimously to nominate my correspondent for the task of putting the ring (*i.e.*, the automobile casing) on the shark. Here let there be recalled the old story of the rats who wished to bell the cat.

HOW THE TAXONOMIST NAMES THE ANIMALS

By Dr. Z. P. METCALF
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ONE of the first steps in securing new knowledge or in advancing from old fields into the unexplored realms which constitutes the forefront of advancing science is the identification of the material with which we are dealing. In zoology this field is called systematic zoology. For many years this science was the most important one in zoology and commanded the best talents of the foremost zoologists of their times. More recently, unfortunately, systematic zoology has fallen into disrepute and the work of the taxonomist is belittled by the geneticist, the physiologist, the ecologist, the experimental biologist, the neurologist, etc. The work of the student of nomenclature is held to be unduly finicky and contributing only to the instability of an unstable nomenclature.

The following thoughts are presented to controvert these ideas, and, also, to present the thought that further progress in zoology in any field is dependent upon sound systematics. In addition, it is hoped that good students may be attracted to the field of systematics to help advance these ideals.

Before we proceed further it would seem worth while to call attention to certain fallacies which have grown up around systematic zoology. First of these is the belief that it is a static science. Nothing could be further from the truth. A careful review of the history of systematic zoology for the past century and three quarters would show that it has made a steady and consistent growth over that period, and one of the things I hope to point out in conclusion is that it will continue to grow and develop. This concept of a static systematic zoology is an outgrowth of the notion of a stable nomenclature which is another of the fundamental fallacies in the minds of many zoologists, including some systematists. There is no such thing as stable nomenclature. It is an illusion. And no substantial progress can be made until we unshackle the minds of the systematists from this handicap. Science is progress. Not a straight line progress but a zigzag progress, with here an advance and there a mistake. To concede that any branch of science is fixed or stable is stifling. Stable nomenclature is no more a possibility than a stable physics, stable astronomy or what not. Shall we ask the geneticist or the embryologist for a stable genetics or embryology? A stable atom almost relegated physics and chemistry to the plain of the dead languages. Any belief that stability leads anywhere but to extinction is erroneous.

Every once in a while we hear a cry that the systematist must return to the principles of Linnaeus. A person making such pleas has no conception of what this means. Perhaps he has never read a Linnean description, has certainly never attempted to fit such a description to any of the host of now known species. There can be no more return to Linnaeus in systematic zoology than there can be to Galton in heredity, to Von Baer in development, or to Balfour in physiology. Linnaeus worked with the limited and conspicuous fauna of Europe, supplemented by a few specimens of striking animals from the then recently explored regions of the world. He had no conception of the hosts of species we now know to exist in all parts of the world.

Scientists, even including systematic zoologists, are like builders would be if they changed their plans constantly while erecting their walls. Is it any wonder that science has a crazy quilt effect? Only a very few scientific builders have really made substantial contributions to the structure as a whole, and no mind has as yet appeared great enough to conceive a plan of science as it should be. As far as I can see, the future will consist of a process of cut and try; discard and replace; trial and error; with a faith that, in general, progress is upward and forward. In this progress in the field of zoology, systematic zoology will contribute no small share, using, as it will, the same methods that are used everywhere else in science.

Systematic zoology is the only phase of zoology which makes a fetish of embalming its mistakes and then erecting these grotesque caricatures as totem poles along the way—totem poles to which each succeeding generation of students must do obeisance as they pass by. This leaves these totem poles as very conspicuous objects along the way and makes it possible for any one to ridicule the whole field of systematic zoology by pointing them out. But I said several years ago:[1]

> True, there is much in systematic zoology that is slipshod, but till statistics can be produced to show that the percentage of slipshod work produced by systematic zoologists is higher than in other fields of zoology, the writer of this article has a temporary residence in Missouri. He is of the opinion, also, that as great a percentage of the work of the systematic zoologist will stand the test of time as the work of the anatomist or any other worker in the field of zoology and proposes to remain of that opinion until time, the great leveler, proves to the contrary.
>
> Linnaeus is apparently not the only genius that has left the back door open and that has "been followed by a crowd of other workers eager to attain to immortality," as witness the great mass of half-digested literature on genetics, say, that has been crowded into the past ten or a dozen years. It would be a sad state of affairs indeed if systematics as a whole were not improving. That there have been occasional backward steps there is no doubt, but on the whole the progress has been forward.

It may not be amiss to call attention also to the fact that there can be no substantial progress in any field of zoology unless it is based on sound systematics. I use sound advisedly, meaning of course in a purely relative way; sound for the time being or temporarily at least; a stepping-stone to something better; without implying, I hope, that any modern scientific Peter is going to erect on this foundation a great permanent edifice of modern science.

Systematic zoology, as I perceive it, consists of three main fields, taxonomy, nomenclature and phylogeny. These fields are constantly playing upon each other and being played upon by other fields of zoology and by other sciences. Discoveries elsewhere change our systematic concepts, and changes in these concepts bring about still further changes. Perhaps we should attempt to define these fields as well as we can with our present knowledge. These terms have not always meant precisely what I shall attempt to make them mean here, but since so much of science is definition, it seems worth while to limit our words as much as possible and attempt to give to them a narrow meaning. There are of course no hard fixed boundaries between these fields. The definitions here proposed are merely an attempt to throw certain aspects of systematic zoology into bold relief.

Taxonomy deals with the descriptions and illustrations of all the prime groups of the animal kingdom. Nomenclature is that field of systematic zoology which is concerned with the names we use for animals but not with the animals themselves. Phylogeny is that branch of systematic zoology which describes the evolutionary descent of organisms and their arrangement into some sort of system to show these relationships. Now obviously these various fields are closely related and interrelated so that a change in one must affect the others. The description of a new genus, the segregation of a new family or order will profoundly affect the field of phylogeny. The proposal of any new taxonomic group will necessitate new descriptions and a rearrangement of certain areas of our phylogenetic tree. Each of these major fields of systematic zoology is important enough for further consideration.

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[1] Z. [P. Metcalf], *The American Naturalist*, 53: 282–288, 1919.

The true basis for all systematics is the description and the illustration, especially the descriptions and illustrations of those two prime groups in taxonomy, the genus and the species. Descriptive science is an art in itself. Many models, good, bad and indifferent, are extant. Descriptions are not necessarily complete in all details. One of the best earmarks of a good description is that it should be revealing. If it is too detailed, it may conceal the true characters. It is worth remembering, however, that what may be considered a complete description to-day may be considered very incomplete to-morrow. All taxonomists have had the experience of trying to correlate the descriptions of several authors only to find that these authors have not used the same sets of characters. In this connection it should be stressed that what are considered important generic or specific characters by one generation may be discarded by the next. Thus one generation of Homopterists stressed head characters and venation and the next stresses the internal phallic characters. The best plan is, perhaps, to take a standard text-book of morphology and make a complete and systematic list of all morphological units. If this list is used, it will enable the systematist to stress the important characters and at the same time be reasonably sure that nothing of importance is missed. If this list is arranged by placing the most important regions closest to the left-hand margin and those of less importance to the right and finally those of least importance furthest to the right in a series of inverted steps, one may determine at a glance how far it is necessary to proceed in any given case.

Illustrations are a universal language that needs no interpreter. That they are not more used in systematics is due to the belief that they are difficult to produce and expensive to reproduce. These conceptions are false, however, for if illustrations are reasonably carefully made, they tell more per unit of measure than the printed page can tell. Another reason that illustrations are not more frequently used is the belief that they can be made only by artists. Any one who can learn penmanship can learn to draw, penmanship being of course a rapid kind of drawing. While a few of us may achieve a penmanship that would be the envy of an engraver, most of us write so atrociously that even our private secretaries get a headache trying to decipher it. Not all of us will be finished draughtsmen, but if any one will put the same amount of time on learning to draw that he devotes to mastering the rules of grammar, punctuation, rhetoric and penmanship, he will be able to make creditable drawings which will aid those systematists coming after to better interpret their meaning.

Neither should it be implied that there is any such thing as perfection in either descriptions or illustrations. This should not deter us, however, from striving towards perfection. I do not mean to imply that it is easy to make an illustration of a tridimensional object in two dimensions. The only real illustrations would be plastic reconstructions, and as yet no one has devised a simple method of doing this or of reproducing the models, even if they were constructed. Neither is descriptive writing easily attained. It is in fact one of the highest of the human arts, and can only be approximated by constant striving. And even if perfection in descriptive science is attained, it can be destroyed by bad interpretation.

Comparisons in descriptive systematics are valuable, but may easily be overdone. Comparisons also may lead to curious results. My attention was recently called to an interesting case. Three American entomologists have recently described new species in a certain genus, each comparing his species with a species described by that great early American systematist, Say. A fourth entomologist, on reviewing the genus, made the interesting discovery that each of his confrères had an entirely distinct species in mind, as the species described by Say. Such illustrations emphasize the need for frequent revisions of considerable groups covering an order or family, at least, so that future taxonomists may make substantial contributions to science.

Keys are the acme of systematic zoology. If they are properly made, they are a guide not only for the neophyte but for the mature student. Simplicity and lucidity should be the guiding principles in the construction of keys, but no matter how carefully keys are made the user must take every precaution in using them. In other words, there are no foolproof keys. Keys should also be so arranged that they may be used backwards as well as forwards. The reverse use of a key will often throw errors into bold relief. Keys should be well illustrated as an aid to the short descriptive phrases of the key. These illustrations may be placed on the same page as the couplets of the key,[2] or the illustrations may be grouped on plates and numbered for easy cross reference.[3]

Keys should always be arranged in contrasting couplets. Multiple choice is confusing to a white rat in a psychologist's maze; but it is confusion worse confounded in a systematic key. Many different arrangements of the couplets have been used. For the most part these may be grouped into four kinds: (1) keys with couplets in juxtaposition;[4] (2) keys with indented couplets;[5] (3) keys with grouped couplets;[6] and (4) a combination key.[7] Each of these types of keys has its advantages and disadvantages and it might not be amiss to discuss them briefly.

The first type of key is easy for the beginner to follow, as the two contrasting members of the couplet are close together and it is easy to comprehend the implied differences. It is also economical of space. One of its chief disadvantages is that it is not easy to use in reverse order. The other great disadvantage is that it is not easy to comprehend the groups that fall under each couplet. This is not a serious disadvantage if the key is purely artificial, but this type should not be used to display phylogenetic relationships.

The indented type of key has one very important advantage, that is, it sets out the groups very conspicuously. It is easy to use in reverse. It has the great disadvantage that it is uneconomical of space, especially in a long key. It is difficult to set in type and, if it is long with one member of the couplet on one page and the other on a succeeding page, it is very difficult to use.

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[2] Z. P. Metcalf and C. L. Metcalf, "A Key to the Principal Orders and Families of Insects," 3rd Ed., 1–23; figs. 1a–225b, 1928.

[3] Z. P. Metcalf, *Jour. Elisha Mitchell Sci. Soc.*, 38: 139–230, pls. 38–70, 1923.

[4] *Idem.*

[5] J. H. Comstock, "An Introduction to Entomology." Complete edition; xi–1044; figs. 1–1228, 1924.

[6] F. Muir, *Proc. Hawaiian Ent. Soc.*, 5: 205–247; pls. 4–8, 1923.

[7] Z. P. Metcalf and G. Horton, *Lingnan Sci. Jour.*, 13: 367–429; pls. 37–43, 1934.

The third type of key has most of the advantages of the indented type of key, although the contrasting characters are not as conspicuous. It is economical of space and it is easy to use in reverse. Similar organisms are of course closely grouped together. It has one of the chief defects of the indented key: if the key is long, members of a couplet may be separated so far on the printed pages that it will be difficult to follow.

A consideration of these various defects led the author to devise a combination key in an attempt to take advantage of all the good features of the other three types of keys and in so far as possible to eliminate most of the undesirable features. This type of key may consist of a combination of the indented type of key with either a key with couplets in juxtaposition or a key with grouped couplets. In any event the key is made up as follows: The primary, secondary and tertiary characters, in a long key at least, are indented; the following couplets are placed in juxtaposition, as in the first type, and appropriately numbered, or grouped, as in the third type. Personally I am inclined to the former method, for this places the minor characters close together, where they may be more readily interpreted. This type of key has many advantages, it seems to me. It is fairly economical of space. The major groups are clearly outlined, and since these are the more important it is fairly easy to use in reverse.

KEY TO CHINESE AND JAPANESE SPECIES OF EOSCARTA

A. Tegmina with base pale, apex black, bicolored.
  B. Tegmina red at base *seminiger* Melichar
  BB. Tegmina ochraceous yellow clouded with black at base *seminiger* var. *crocea* Metcalf and Horton
AA. Tegmina not bicolored.
  B. Tegmina uniformly colored.
    C. Head and pronotum pale yellow or reddish *borealis* Distant
    CC. Head and pronotum dark brown or black 1
      1. Abdomen black 2
      1. Abdomen reddish brown basad. Legs brownish *karschi* Schmidt
      2. Crown not as long as broad. Abdominal segments bordered with yellow. Legs black *assimilis* (Uhl) Matsumura 1903a: 18 (Japan)
      2. Crown as long as broad. Abdominal segments not bordered. Legs brownish yellow *fusca* Melichar
  BB. Tegmina not uniformly colored.
    C. Tegmina black with two yellow spots near the apex, one on the costal margin, the other at the apex of clavus *bimaculatus* Matsumura 1907b: 106 (Formosa)
    CC. Tegmina not black with two yellow spots 1
      1. Tegmina orange red with small black spots in the apical cells *laoensis* Schmidt 1918a: 203 (Tongking)
      1. Tegmina variously colored 2
      2. Pronotum uniform brownish yellow *aurora* Kirkaldy
      2. Pronotum not uniform brownish yellow 3
      3. Abdomen blackish, shading to reddish basad, segments bordered with red *melli* Schmidt
      3. Abdomen dark brown, segments not bordered 4
      4. Length 4.0–5.0 mm. *assimilis* var. *apicalis* Matsumura 1903a: 18 (Japan)
      4. Length 7.0–10.0 mm. *sonalis* Matsumura 1907b: 106 (Japan)

A brief description of my present method of making keys may not be amiss. A survey of the material usually reveals some contrasting characters by means of which the material may be divided into two groups. These contrasting characters are then taken as primary couplets. The two members of the couplet are then numbered 1. and 2. and typed on 5 × 8 cards in order that they may be filed in the standard 5 × 8 card drawer. The names of the species that fall under 1. are then written on this card and likewise for 2. These primary groups are then divided into secondary groups with their characters written on separate cards and numbered 1.1 and 1.2 and 2.1 and 2.2, respectively. So with tertiary, quaternary and all other groups to the end. By this method it is easy to use the key, to discover its defects and to remedy them by minor corrections on the cards, or to discard a couplet substituting a new and better couplet; to raise or lower the rank of a couplet; in fact, to make any change whatsoever, without completely destroying what has been done and making a fresh start.

NOMENCLATURE

Nomenclature as defined above has to do with names alone. It does not determine whether a genus or species is valid, but it does determine what name should be used for any given unit of the Animal Kingdom.

Nomenclature or the determination of valid names is based on laws. All laws are based on precedents and frequently run counter to common sense, whatever that is. Hence, the law does not always seem to be sensible. Not infrequently zoologists who have made no study of nomenclature want to overthrow not only the results of the study of nomenclature but even the laws thereof. Such actions must be condemned. Laws should be not only the results of precedents but should also be the outgrowths of experiences.

The laws of nomenclature are not many. They have an honorable history and are the results of the ripest experience of some of our best systematic zoologists. They should be followed, therefore, until there is common concurrence that they can be improved. These laws of nomenclature have to do principally with the forms of generic and specific names and names of other groups; with what constitutes publication and with priority of publication. Most of them are simplicity itself. They are, however, not always applied with wisdom, hence the confusion that arises.

These laws must not be *ex post facto*. To make them retroactive would destroy nomenclature entirely. Let me illustrate. We pass a law making the designation of genotypes one of the prime requisites of the description of a new genus; if we made this retroactive fully half of the generic names now in use would be invalid. Occasionally we hear proposals made which would not stand the test. Suppose, for example, we were to suggest that all names not accompanied by adequate descriptions of the things which they are supposed to designate shall be discarded; nothing could be fairer, but immediately the question arises, Who shall determine what is an adequate description?

There are two other functions of nomenclature which may be easily overlooked: The preparation of standard bibliographies and the preparation of catalogues. The size of these tasks may be appreciated best by some concrete examples. I estimate that the insects known as the higher Homoptera constitute about one-five hundredth of the species of the Animal Kingdom. The bibliography for this group comprises more than 8,000 titles which have been published in at least 1,000 separate books and 900 different magazines. The card cataloguing and collating of this material is no small task.

The task of cataloguing this material is so vast that it is doubtful if one generation can possibly catalogue the material for the next generation. The group

Homoptera has perhaps 3,100 known genera and, it is estimated, about 20,000 species. To publish complete catalogues of this group alone would involve about 20 volumes, each of at least 1,000 pages. And this represents the accumulations of less than 200 years. Shall we raise the question, "What of the future?"

Another function of nomenclature is to define the fundamental units of the Animal Kingdom. If this definition is accepted, we may realize how much work there is yet to be done in the field of nomenclature when we attempt to get from a group of zoologists a definition of the concept species. Yet the very attempt to define such concepts is worth while, and the contributions that nomenclature can make to both taxonomy and to phylogeny by making this attempt are valuable.

Linnaeus had in mind only four taxonomic concepts. The genus and species were the most important, but in addition he had higher groups than the genus, which we may call orders, and lower groups than the species, perhaps best designated by the name race. Let us be clear, however; Linnean taxonomic concepts are to be compared with modern taxonomic concepts by courtesy only. Linnean genera, for example, are more nearly of the rank of modern superfamilies. His species are of specific rank only in those cases where a region is inhabited by a single distinct species of a genus. Linnean species are, therefore, more nearly of the rank of genera. And his so-called orders are really classes or groups of modern classes.

Modern nomenclature recognizes no less than sixteen categories, ranging from kingdom to individual. Each of these is elevated or depressed by adding the prefixes super or sub, so that in reality there are more than thirty grades of taxonomic concepts. Each of these grades is of use not alone to the systematist and phylogenist, but to the general zoologist. It is too bad that there is not a thoroughgoing recognition of this idea by the morphologist, embryologist, geneticist and workers in zoological fields other than systematic zoology. Most of the morphology, or what not, is not the morphology of a given species but of a family, a tribe or even an order. If this idea was generally accepted, the worries of the systematic zoologist and of the zoological worker in other fields would be largely eliminated. The specific or generic position of most of the material handled by the general zoological worker is not of prime importance, and it will not be until we have a firm foundation of the morphology, let us say, of the orders. Morphologists of future generations may concern themselves with the family, the tribe, the genus or the species. If the work is well done, it will take at least several centuries for the morphologists to take each of these steps, and by the time morphologists are working with species the taxonomist will have developed new refinements of techniques, so that the race or form will be elevated to prime rank and the species will no longer be of importance.

The taxonomic categories which have been proposed may be arranged to best advantage in the form of ascending steps.

TAXONOMIC DIVISIONS OF THE ANIMAL KINGDOM

KINGDOM
Branch
Series
PHYLUM
Division
CLASS
Legion
ORDER
Cohors
Phalanx
FAMILY
TRIBE
GENUS
SPECIES
Variety
Individual

Obviously, if we could gain a toehold anywhere on these taxonomic steps, we could climb upward or downward, as the case may be, to the groups of greater or lesser rank. But this is difficult to do. The top step, Animal Kingdom, and the bottom step, the individual, are generally accepted. No attempt is made to define them, so far as I am aware, save by philosophers, who should know better, and by inmates of state hospitals, who know no better.

Let us, therefore, without fear that we may stub our toes going up or stumble going down, attempt to define three of these prime groups, the species, the variety and the genus. I am under no illusions that these definitions will be accepted even by the majority of systematic zoologists. If they were thus generally accepted, they would be so innocuous that they would be meaningless. If we can get a definition with which men will come to grips, there is some hope for taxonomy as a science.

A species is a prime group of animals which reproduces its like in nature. A variety is a digressing geographic or ecologic group reproducing individuals which are constantly similar to, yet consistently atypical of the species. A genus is a group of species with outstanding characteristics which are recent descendants, in a phylogenetic sense, of a common fossil ancestor.

Now, having dutifully accepted these definitions, or cast molds for better ones, we can climb the taxonomic steps with the utmost ease. And definitions for tribes or families or any other taxonomic group may be constructed. We may likewise speak of subtribes and superfamilies as if they were real entities and not merely the figments of an imagination too deeply involved with boxes of dried insects, or cases of mollusk shells in the dusty attic of some great museum.

PHYLOGENY

Phylogeny is that branch of systematic zoology which describes the evolutionary descent of organisms and their arrangement into some sort of system to show these relationships. I know of no field of zoology requiring such a broad philosophic grasp of fundamentals, such thorough scientific bases and at the same time such an imagination as that required of the real phylogenist. Let us examine the reasons for this statement.

Phylogenetic relationships are usually shown in the form of family trees. These of course are pure artifacts due to our limitations of a two-dimensional printed page in a three-dimensional world. The facts are, that for phylogenetic purposes we need a four- or five-dimensional space, perhaps a multiple dimensional space. For present purposes it is enough for us to comprehend the difficulties of the construction of our two-dimensional phylogenetic tree. For purposes of illustration, let us assume that we had never seen a tree of any kind. We know nothing of root, trunk, limbs, branches, twigs or leaves. With this lack of knowledge, some one dumps on our laboratory table a cart-load of leaves of all kinds and we are told to sort out the oak leaves from all other kinds and to reconstruct a particular oak tree, root, trunk, limbs, branches, twigs, and to place each leaf with its petiole on the correct twig, with each twig branching at the proper point, with branches in proper relation to all twigs and to the main limbs, and finally with limbs symmetrically arranged on the trunk. If you can comprehend such a task, you can catch the vision of the task confronting the phylogenist who attempts to reconstruct the phylogeny of a group of animals. If I were to ask you to reconstruct even the main limbs of the oak tree that grows by your garden gate, which you have seen each morning and each evening as you hurry about your daily task, you would say that it is impossible.

The size of the task, however, shall not deter us. We will struggle with the problem, and each advance in every other field of zoology will cause us to shift a branch here and there; to place two leaves on this twig where only one grew before; to erect families and superfamilies; to merge and combine genera and species.

The relations between phylogeny and morphology are perfectly obvious. But the refinements of the morphologist have outrun the phylogenist. Elsewhere[8] I have pointed out the relation between zoogeography and phylogeny. The relation between embryology, development and phylogeny has lagged because the old phylogenetic law has fallen somewhat into disrepute. The trouble was not with this law, but with the statement of the law, "Ontogeny repeats phylogeny." If the law is restated, "Ontogeny *reveals* phylogeny," it takes on new meaning and opens a new continent to discovery and exploration. No one really meant to imply that an organism in its short embryonic development covering a few days or weeks could possibly repeat the stages of its racial history, covering untold centuries. If we really knew the ontogeny of any group of animals, we would have a photograph, perhaps somewhat dim, of our hypothetical phylogenetic tree. Therefore, I believe, I am safe in saying that the next great advances in phylogeny will be made in the area of embryology and development which has been thoroughly correlated with morphology and zoogeography.

HISTORY

Systematic zoology has a long and honorable history. As a matter of fact, like political history its beginnings are shadowed in antiquity. Primitive peoples everywhere gave names to the animals around them, and a study of these names will always show a primitive understanding of relationships. Aristotle summarized the knowledge of his day with his scheme of classification, and thus matters stood for more than twenty centuries.

The next great contribution was by John Ray, the Englishman, before 1700. This was the fundamental concept of the species. It was followed soon thereafter by Linnean binomial nomenclature in the middle of the eighteenth century and by the phylogenetic concepts of Lamarck at the beginning of the nineteenth century.

Around and through these three great concepts has been erected modern systematic zoology, with its great museums, with marvelous collections and their trained staffs of specialists in all groups of the Animal Kingdom.

There are also four periods of systematic zoology which are worthy of recognition, for they help to explain the present condition: A primitive period extending down to about the beginning of the eighteenth century; a period of expansion, from about the beginning of the eighteenth century to the early years of the nineteenth century; a period of exploration, beginning with the nineteenth century and extending to about the middle of that century; and lastly, a period of specialization, beginning before the middle of the nineteenth century and extending to modern times. These periods must not be thought of as distinct entities separated by cataclysmatic revolutions; but as periods which merge into each other so gradually that it is, of course, impossible to give exact dates for their beginnings and endings. Each period was the outgrowth of the period that preceded it. Before one period vanishes, another is gradually growing until it overshadows that which has gone before. Thus we could not have a renaissance in human thought and human science without men becoming dissatisfied with the primitive names which were given to animals. Out of this dissatisfaction grew Linnean binomial nomenclature and a desire to name all the animals in the world. Hence, the old primitive notions faded out during the eighteenth century, and Linnaeus and his pupils attempted to name the animals from all parts of the world, sometimes from actual specimens, sometimes from the tales brought back by explorers of remote regions of the world.

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[8] Z. P. Metcalf, *Jour. Elisha Mitchell Sci. Soc.*, 49: 97–107; figs. 1–4, 1933.

Gradually there dawned in the minds of systematists of this period the idea that perhaps all was not what it seemed; perhaps some of the tales were overdrawn, that dragons were not rampant in the remote regions of the world. On the other hand, there was perhaps the notion that there were as good fish in the sea as had ever been caught. So gradually expeditions were sent out, and we had a period of exploration which culminated in the great expeditions which contributed so much to our knowledge of the Animal Kingdom of the world.

When this mass of material commenced to flow towards the centers, there developed a period of specialization. Men were no longer systematic zoologists, but became specialists in restricted areas. They were mammalogists, ornithologists, herpetologists, entomologists, conchologists, or what not. Soon there were no entomologists, but coleopterists, dipterists, lepidopterists, each with his own techniques, his own language, his own special tribal ceremonies.

To-day the tendencies are toward narrower and narrower fields. This is as it should be. The wealth of material, especially among the less conspicuous insects in the tropical regions of the world, is absolutely beyond belief. The size of the task confronting systematic zoologists is hardly appreciated, even by the systematists themselves.

> Perhaps we may appreciate the growth of systematic zoology by a few contrasts. One hundred and seventy-five years ago Linne wrote the 10th edition of the Systema Natura. It was a small volume of 821 pages containing the descriptions of all the animals then known, arranged in 312 genera containing about 5000 species. The insects of the Order Homoptera were included in one genus with 42 species and occupied 5 pages or about 1/165 of the whole work.
>
> What of today? The same group is arranged in 2 Cohors, 11 Superfamilies, 34 families, 65 subfamilies, about 3100 genera and I estimate about 20,000 species. And the end is not yet. I never receive a collection from the tropical regions of the world, be it Cuba, Central America, Colombia, Surinam, Brazil, West Africa, East Africa, Madagascar, Java, Philippines, or New Guinea in which the new species are not numerous. And of this group these regions have never been systematically collected.
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> But to describe completely these 3100 genera and 20,000 species would require at least 200,000 pages or 250 volumes the size of the Systema. To describe the Animal Kingdom assuming that the Linnean proportion holds would require 165 x 250 volumes of 800 pages or 41,250 volumes. Perhaps I should not, but I must of necessity, remind you that as carefully as I can estimate the Homoptera represent not 1/165 of the Animal Kingdom as Linne had it but about 1/500. Our library of Systematic Zoology contains not 41,250 volumes but 125,000. Comments are superfluous.[9]

FUTURE

What of the future? Well, the life of a prophet is easy. If the prophecy comes true, he can always say, "I told you so." If it fails, no one remembers. I am reminded of the famous Mother Shipton's prophecies. Every one remembers, "And carriages without horses shall Run." But every one has forgotten the next member of the couplet, "And the world to an end shall come in the year Eighteen Hundred and Seventy-one."

With this as a background, I do not hesitate to prophesy that systematic zoology will come into its rightful place again in the sisterhood of zoological sciences. That it will be more closely correlated with the other branches of zoology. That there will be closer relationship among the branches of systematic zoology, nomenclature, taxonomy and phylogeny. But that there will be also a much greater interplay between systematic zoology and morphology, embryology, genetics and zoogeography than there has been in the past. Advances in these sciences will be reflected more quickly than at the present. This ideal can only be attained if the great bibliographic services like the *Zoological Record* and *Biological Abstracts* are not only maintained but expanded. It can not be attained, however, if we do not have a careful reworking of the accumulations of the last two centuries. Especially must we have comprehensive bibliographies of family or larger groups so that it will not be necessary for each student to traverse the same road. Complete catalogues must also be published, so complete in all details that the chances of improvement will be so slight that students will turn their eyes to the future and not to the past. And lastly, we must have comprehensive reviews by continental areas of the larger groups of the Animal Kingdom; so detailed and so well illustrated that he who runs may read and so simple that the beginner may comprehend.

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[9] *Idem.*

As specialization increases, as the problem of publication becomes more acute, there should be formed somewhere an international exchange for reprints. Such an international exchange would receive subscriptions from workers for reprints in their specialties and authors or journals would send sufficient reprints to fill the subscription list with a reserve for future demands. Such a service would be of immense value to systematic zoology and the difficulties in the way of its establishment are not insurmountable.

This is a gigantic program, and there is in it nowhere a place for a static science. Things that are alive must grow.

MUTUALLY INTERPRETATIVE RELATION BETWEEN HUMAN AND AVIAN NATURAL HISTORY[1]

By Professor WM. E. RITTER
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WHY do I use the antiquated term natural history instead of the thoroughly modern term biology? Because I want to emphasize the truth that natural history is antiquated if being alive is antiquated, and not otherwise.

Were the word biology to be used in the original meaning of its Greek ancestor it would mean almost exactly what natural history meant as used by two of the greatest students of animate nature that have ever lived. I refer, as probably most naturalists would surmise, to Aristotle and Charles Darwin.

The meaning in common of the two terms was "way of life." With the Greeks *bios* meant the way of life, especially of men, but also of animals generally. It included birds rather specially it would appear from the famous play, "The Birds," by the great comic poet, Aristophanes. And with Aristotle natural history meant way of life of animals generally but included man rather specially, as shown by the great place man has in his "Natural History of Animals."

Now way of life is first and foremost way of acting—way of doing things. It is behaving. It is conduct. And particularly significant is the fact that this implies individual organisms, each composed of many parts so related with one another that the individual is able to act by means of its parts in such fashion as to meet its own necessities, inclinations and desires. The separateness of every individual from every other is manifest in the fact that each one must act by means of its own parts. No individual can act by the *direct* means of the parts of any other individual. No one breathes or talks by means of the lungs and mouth of somebody else.

Originally and fundamentally, then, both natural history and biology meant and really always must mean the mode by which individuals act so as to continue their existence as living bodies and to continue the existence of the race or species.

Foundational therefore to all knowledge of the living world (and for that matter of all the world) are individual bodies so organized as to be alive. And, strikingly enough, among these bodies are the very ones that do the knowing! So it falls out that among the ways of life of certain of these bodies is learning and knowing the very subjects we name natural history and biology. Let us come down to the business in hand, that of men and birds.

We are all vertebrates; no room for intelligent question about that. This is only another way of saying that we are all built on the same ground plan. For this occasion it is enough to notice only two items in this plan: our two pairs of limbs and our heads.

Although the grossly obvious limbs of men and birds are extremely unlike in many anatomical points they are unmistakably alike in many other points. Hardly any thoughtful person can fail to be impressed by this two-fold truth.

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[1] Modified from a paper read at the annual meeting of the Cooper Ornithological Club held in Berkeley on April 16, 1937. It is a sort of epitome of portions of two books by me: "The California Woodpecker and I" a study in comparative zoology (now in press); and "Nature in the Light of Science, Art, Philosophy, and Religion" (nearly ready for the press).

So likewise as to heads. No one can avoid taking some notice of the fact that a bird has two eyes, two ears and a mouth in its head no less truly than has a man, despite the great difference in general shape and get-up of the two heads.

But what is specially to the purpose in this disquisition is comparison of the way men and birds use the parts under consideration—how the members are utilized by their possessors in their ways of life. In their typical mode of locomotion birds so far outstrip us humans in our typical mode that we never pretend to be in their class. Their way of life, in which their fore limbs play such an essential part, gives them an enormous advantage over us as judged by the same criterion. What plodders we humans are when we go a-foot, as compared with birds when they go a-wing!

But exceedingly important as is travel for both birds and humans this is far from the whole story. Both must do many other things in order to keep on living and living as they like to live. So we turn to the other anatomical member under consideration, the head, and reflect a bit on the use birds and men make of this member in their respective ways of life.

Perfectly obvious, is it not, that both use it to several common ends? For instance, the fact that in both the mouth is in the head makes it inevitable that the head should be extensively utilized by both for eating, to say nothing of other activities involved in the nutritional business. Then there is the utilization of the mouth by both in the production of sound—of vocalization. The importance of this to both, but especially to humans, far surpasses, from one point of view, its importance in eating and breathing. Reflect, also, on the extent to which both manipulate their eyes in seeing by means of the head-neck combination. Herein birds are specially expert in several respects.

Now comes a matter that, although it has received much attention from some directions, has never, so far as I know, received enough or of the right kind from any direction. I refer to the principle of correlation among the parts of an individual animal. While the principle applies to almost if not quite all the myriad parts (including the cells) it is specially obvious and important as between the head and the fore limbs of the higher vertebrates—the very parts that force themselves upon our attention in this study. Surely no one needs reminding of the way a bird uses its head and wings cooperatively—except, perhaps, as a reminder of how much more extensive and nice the cooperation is than in cursory notice one takes account of.

As for the way a human uses his head and fore limbs cooperatively—well, let anyone keep a record of all his movements for a busy day and see what fraction of them falls into the class of head and arm-hands cooperation. No one could fail to be impressed by such a study—if he never was before—with the extent to which not only his way of life but his life itself are dependent on this combination of these anatomical parts, and on his activities by means of them.

Indeed so obvious are the ways of life of us humans dependent upon the cooperation and coordination of these members, especially if any skilled hand work is involved, that we take it as a matter of course and pay little or no attention to this portion—the strictly psychobiological principles involved.

But there are other vital principles involved that are far from obvious to common experience, and so enter very little or not at all into conscious knowing and thinking by the vast majority of persons. I refer to the great question of how we mortals and birds come to be the possessors of parts so remarkably related to and cooperative with one another. The question divides into two distinct portions. One portion is that of how the relation comes to pass in the development of the individual—human, bird, lizard, frog, fish or any other member of the vertebrate phylum. The intricate sciences of embryology and genetics struggle with this portion of the question and have gained much information concerning it. What is more, they have secured a good deal of real understanding in connection with it.

The other part of the question is that of how the individuals not merely as such, but as members of races, come to have parts thus correlated and cooperative. Paleontology is the chief science which gathers specially relevant facts for the struggle with this question.

An enormous accumulation of facts of both anatomy and physiology enables students to conclude that the coordinativeness and cooperativeness of the parts of an animal must be in its nature at the various stages of its *individual development* and of its *racial development,* as well as in its nature as shown in those activities that make the individual alive or living.

Observations on the anatomy and physiology of animals now living and observations on the anatomy of animals long since dead, both individually and racially, and reasoning on all the sense data in accordance with Aristotle's principle of complete reality (*entelecheia*)[2] seem to compel us to conclude that just as we must, and in practice actually do, accept the living individual animal (especially our consciously knowing individual selves) as a whole at any particular *moment,* so we must accept the individual as a whole (a complete reality) throughout *all the moments* of its life. A particular bird is as truly a living reality at the moment of hatching, say, as at any other time during its life, including the moment just before the depredator's fatal wound or the hunter's fatal shot. So likewise as to a particular human. Its real aliveness is not limitable to any single moment for the sufficient reason that it is involved in the aliveness of a great host of parts having different rates of vital action. For example, the rate of "flow" of a nerve current is very different from that of the blood current, yet both are essential to the vital existence of a bird or a man. That the sciences of living nature are being driven to such a conception under the designation of organicism, is, I think, beyond doubt.

Although racial development (evolution of the most usual meaning to-day) is somewhat more difficult to interpret from this standpoint, it must, I am quite sure, be so interpreted. Thinking about evolution always presupposes a racial line, or line of descent. Nor is there anything known to science for such a line to be composed of except individual organisms, capable of maintaining themselves in the living state and of propagating their kind. Mr. Darwin's constantly invoked idea of "descent with modification" and the French evolutionists' idea of transformation are meaningless generalities as applied to living nature as a whole, except as they envisage uncountable millions of individuals composing the ancestral line of each and every individual now living. And not only that: every one of these ancestral individuals must be envisaged as composed of many parts essential to their individual existence and through which modification and transformations new kinds of individuals have been produced.

Every individual in the ancestral line of any kind of modern birds (of my woodpeckers, for example) in its long course back to its presumed reptilian ancestors must be imagined as possessing two pairs of limbs and a head modifiable in the direction of those actually possessed by the birds of to-day.

So far this imaginary picture contains little beyond what the orthodox evolutionary picture contains, but now comes a point that the orthodox picture does not contain in any truly kinetic sense: every one of those ancestors must have depended for its aliveness upon using its limbs and head cooperatively no less than does its descendants of to-day. One of the major implications of this brings the principle of correlation of parts into the racial life to correspond with its application in the individual life. For another thing, it implies that as to parts in which the correlation is most vital for the existence of the individual the existence of each part so related is dependent on the existence of its correlate. It implies that the bird's head as such would not exist except for the existence of the bird's limbs as such. Since in the case of birds the mode of locomotion is the most definitive quality in their way of life, we are bound by the logic of the general problem to consider with special care the body parts most concerned, not only as to the structure and function of the parts in birds of to-day, but as to the modifications and transformations that have taken place in the ancestral line to produce these parts. Despite the enormous mass of observational evidence now available from anatomy, physiology and biochemistry, that it is in the very nature of a living body to consist of mutually dependent, interacting parts, when the question of how the body comes to be thus composed, very many moderns (seemingly most analytic students, particularly if their specialty happens to be genetics) are in much the intellectual state on this matter as was old Empedocles. For him, recall, the parts of a living body come together "not all at once, but coming together at their pleasure, one from this quarter, one from that."[8] While it is true that, so far as I know, no modern biologist regards, as did the ancient Greek, love as the "center of the whirl," the question of what brings the parts together is less important than the supposition that originally they were independent—some in one quarter, some from another. An organizer or a psychoid, for example, may appear to some more scientific than "love" as an agent for doing the trick. But really if one's curiosity goads him to inquire about the intrinsic nature and the origin of the agent, I fail to see much if any advantage of these modern over the ancient explanations.

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[2] W. D. Ross, "Aristotle Selections," Glossary. 1927.

While it has sufficed for our discussion thus far to speak of the head and the limbs as the correlated parts, we must now be more specific, more analytic. No one will hesitate as to what some of the most important specifications must be. The muscular and neural parts of the structure involved must certainly be noticed. So far as concerns the head the brain is a crucial sub-part. Even "brain" is too general if one is eager to understand the ways of life of birds or any other vertebrate animals; the cerebral part of the brain must come into special reckoning. I am here assuming that along with my reader's familiarity with the wonderful activities of birds in breeding, nest building, incubating, caring for the young; also with their abilities in meeting their necessities for food and other things, there is connected some knowledge of the dependence of these activities on the anatomical and biopsychical nature of individual birds; and that in this nature the brain is of foremost importance.

The knowledge we now possess of the dependence of avian ways of life on the use birds make of their body parts acting cooperatively and our knowledge of the racial history of birds and their parts lead us to expect that many of the parts would be a sort of anatomical record of that history. Considering the great dominance of locomotion in their activities, we ought to expect that the record suggested would be especially distinct in the brain and the fore limbs, these being the parts most directly involved in locomotion.

Recurring to the other member, humans, of our comparative duet, we are justified by all the best established knowledge of living things in presuming that the general principles relied upon in interpreting birds will hold for interpreting humans. These principles are: The unity of ground plan of birds and humans, making them namable as vertebrates; the dependence of each individual existence and way of life on its ability to use its parts in cooperative action so as to assure its own existence and enable it to produce other individuals like itself; the existence of racial or ancestral lines composed of myriads of individuals, the existence of each of which must have depended on its parts in like fashion with the dependence of its living descendants; and finally the modifiability by natural causes of individuals to produce new *kinds* of individuals.

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[8] Charles M. Bakewell, "Source Book in Ancient Philosophy," p. 45, 1907.

Let us put now a typical bird (one of my woodpeckers, for example) and a typical human (my humble self, for example) alongside each other to make the comparison unqualifiedly concrete. The woodpecker's wings and my arms and hands may receive first attention, since "way of life" of each of us is foremost in interest. Nothing either of us can do with our heads can be so momentarily striking as the bird's winged dart into the air after flying insects or in play; and the arm-swinging of my morning gymnastics. But no spectator of our performances could be oblivious of the fact that our brains are concerned in what he may see us doing, despite the exceeding inconspicuousness of brain action. How unfortunate that the activities that go on in the brain and nerves of an acorn-harvesting-and-storing California woodpecker, and an acorn-harvesting-and-storing California Indian woman, can not be thrown on the screen side-by-side with the activities of wings and arms-hands of the performers! We must depend on the neurologists and physiologists for the brain-nerve portion of this comparison. By dint of great labors they have made much knowledge available for our enterprise. Note the results as applied to these two performers: While the woodpecker can beat the Indian all hollow at gathering acorns from the trees, the Indian can beat the woodpecker still more at storing them and utilizing them for food.

The reason for this is perfectly obvious so far as the fore limbs are concerned: The birds can reach the acorns with the greatest ease even on the tops of the tallest oaks, or from oaks in the most inaccessible places—for ground travel. But they must make a separate trip, forth-and-back, for every nut, their fore limbs being entirely excluded from direct participation in the business. No collecting basket or bag here—only the mouth for picking and carrying, even this being of only one nut capacity!

And as to storing—well, that these woodpeckers do a remarkable job is widely recognized, but it is remarkable only as a *bird* job—not as a *human* job. For even the Indians often construct a storage place for the nuts that, simple as it is, requires more varied and complex activity and is, on the whole, much more efficacious than the sort of storage place made by the woodpeckers. Furthermore, the Indians subject the acorns to various quite elaborate processes in preparing them for eating, of which the woodpeckers do nothing whatever and about which they know nothing.

In connection with the fore-limbs aspect of the comparison, it is obvious that an extensive set of activities involved in the Indian way of life with respect to the nutritial function is performed by means of these limbs, modified into arms-hands, that is, organs for grasping and holding. This set of activities is wholly absent from the woodpecker's way of life, due to the fact that these members have been modified into wings, organs for a unique and exceedingly efficient way of travel.

Considering the difference in the avian and human brains that should correspond (according to the principle of correlation of parts) with the different uses the two kinds of creatures make of their fore limbs, let us first notice what the comparative anatomy of the two brains shows. It is a commonplace of the anatomy and embryology of vertebrates that the brain presents a ground plan quite as clearly recognizable as is the ground plan of the backbone, the eyes or of the blood-circulating system.

Embryology makes clear the beginning of the brain by modification of the front end of what becomes the spinal cord into three enlargements known as primary vesicles. By extensive growth and modification of these vesicles all the variously sized and shaped brains of the many classes and orders of vertebrates come into existence. Although the modifications in each of these vesicles are extensive they are much greater in the first, counting from before backward, than in the other two. While the parts of the adult brain derived from the second and third vesicles are present in all vertebrates, from fishes to humans, certain parts derived from the first vesicle are almost wholly lacking in fishes as less evolved members of the branch; while other parts derived from this vesicle are present in great size and elaboration in the more evolved members.

On the basis of these anatomical and developmental facts investigators have adopted the terms "old brain" and "new brain." These terms are expressive and quite justified, provided one never forgets that they refer to two parts of one and the same brain and not to two distinct brains.

What this nomenclature means is that while all vertebrates from the evolutionally oldest (fishes) to the evolutionally youngest (humans) possess the oldest portion of the brain, only the evolutionally youngest possess the new brain in its largest, most highly elaborated form. The cerebrum, which constitutes by far the chief mass of the human brain, hardly exists in fishes. If even its beginning is present here it is so small and indistinct as to be hardly recognizable.

Now for the bearing of all this on the comparison of the human and the avian brains: While in both the cerebrum is unmistakenly present, in the human brain the cerebrum, with the cerebral cortex, is enormously larger in proportion to the entire brain than it is in the avian brain. I know of no serious effort to determine the quantitative relation between old brain and new in either men or birds. Mere inspectional estimates made by several persons on the basis of published figures agree on about twenty (old) to eighty (new) for the human, and ninety (old) to ten (new) for the avian. From all that is now known about the neuro-muscular system (anatomical) and the sensory-motor system (functional) it would seem beyond question that the striking differences between human and avian brains are correlated with the most striking differences between the two groups in their ways of life. No doubt many other body parts are involved in the correlation, but these parts must be preeminent in the involvement. Accordingly, we may say the great dominance of new brain over old brain in humans may be viewed as a sort of anatomical record of the great dominance of the activities humans perform by means of their fore limbs in operating on the external world; and of the highly complex activities they perform by means of their mouths and other vocal organs for communicating with the animate world, especially the human portion of it. Contrariwise, the great dominance of old brain over new brain in birds may be viewed as such a record of the great dominance of the activities birds perform by their fore limbs in moving from place to place and of the relatively simple activities they perform by means of their mouths and vocal organs for purposes of communication.

It will be remembered that our comparative illustration called attention to the great advantage (on the whole) the Indians have over the woodpeckers in utilizing acorns for food; and that in the main this advantage is in the fact that the Indian's hands are utilizable for the purpose, while the bird's wings are not at all so utilizable—*directly*. No reference was then made to the fact that the structural-functional conditions on the basis of which hands are utilizable in the acorn business makes them utilizable in hundreds of other businesses. It is doubtful if any single item in the entire way of life of animals has been a more potent determiner of a group's status in the whole animal world than the utilizability of the human fore limbs, especially the hands, for hundreds, even thousands of different purposes. Recur again to the Indian woman in the acorn business, as the first in a comparative series. While she is manipulating (note the relation of the word to *manus*, the hand) the acorns, another woman of some other tribe may be weaving baskets, while still another is weaving rugs, another decorating a papoose carrier with beads, and so on. Simultaneously an Indian man somewhere may be chipping a piece of flint for an arrowhead; another somewhere else may be pulling his bow string to speed his arrow at his prospective victim; another may be fashioning a bit of copper or silver into a finger ring, while yet another may be making a flute from a long bone of some large bird.

No one can follow such a lead, taking Charles Darwin's attitude toward natural history and the origin of man, and fail to enter finally the whole world of industrial and fine arts.

Then there is the other aspect of the same great scene—the aspect that exists in virtue of the utilization of the human mouth and vocal organs in producing language. That speaking as men do speak is no less certainly dependent on neuro-muscular activity than is weaving, writing and piano playing, no informed modern doubts. So it comes to pass that the way of life of the human species taken in its complete reality shows us still another unbroken series typified by the Indian mother's simple speaking to her infant, through the measurably complex tribal chant, on to the oratory of a Demosthenes or a Pitt; or to the opera singing of a Schumann-Heink.

The scene is not yet complete even in outline, for it does not contain a hint of the remarkable interlocking of the arms-hands series and the vocal organs series. Starting with the Indians again, notice some specially gifted individual manipulating a crudely fashioned paint brush to mark some rock with characters that stand for or symbolize objects and acts long and well known and talked about by him and his kindred. The lead thus presented brings us finally to such productions as Plato's "Republic," Mommsen's "Roman History" or Shakespeare's "Hamlet." Here is presented also a way of life, a mode of activity, that illustrates a functional correlation of parts in the case of head-and-hands that is peculiarly significant. The reference is to mathematics. We read: "Mathematics is a game played according to certain simple rules with meaningless marks on paper."[4] This definition is, according to Bell, by David Hilbert, said to be regarded as the foremost living mathematician.

While such a conception may seem to some persons a "drastic deflation of mathematical truth" (Bell), to a naturalist it appears to bring the activities involved into line with the conception of natural history as one of man's most highly specialized and important ways of life. Would any cultivator of "pure mathematics" contend that the reasoning involved might be carried even theoretically by the mind without marks of any sort or anywhere either on paper or on the tablets of his imagination? Hand activity seems to be as indispensable to mathematics as is brain and mind activity; and the higher, more involved and recondite the reasoning involved, *i.e.*, the more elaborate the equations or other language employed, the more indispensable the hand activities, for the more difficult it becomes to carry the language in the mind exclusively. This probably explains the fact that a professedly idealistic philosopher or "thinker" banks more on the pure reason theory of mathematics than does a working mathematician himself.

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[4] E. T. Bell, "The Queen of the Sciences," p. 21, 1931.

Once the idea of a living animal organism is seen to involve the coordinate idea of a whole-with-its-correlated-parts, adapted to its environment, it becomes clear that all manual activity, including every phase of scientific research, expended upon any part of the environment, is basically and organically in behalf of the welfare of the acting being and its kind. All such activity is adaptive or mal-adaptive. It affects in some way, either for good, bad or indifferent, the acting individual or its race or both.

Pure science, pure art, pure thought, pure anything in the sense of being no part of the way of life of living individuals seems to be pure fiction; that is to say, is objectively non-existent, no less for humans than for birds or any other species. The deepest responses to stimuli, impulses and acts put forth by every animal being is really for well-being—well-being of the individual *qua* individual and *qua* race or kind or species.

Returning to our concrete examples—California woodpeckers, California Indians, and my own self—the question arises: How is it that I can utilize my head and fore limbs toward knowing and understanding the others of the trio so much more extensively than either of them can or at least do?

Taking the woodpeckers first, I approach the general question through a particular question: How is it that I could show the birds how to act for their own good in the acorn business much more effectively than they frequently do act, despite the fact that their good and not mine is concerned? For instance, I could easily tell—even show them—that there is no necessity to store nuts (as they quite often do) in places where they can not possibly get them, however much they may need them, for food. Or I could easily inform the birds of the risks they run from the orchardist's shotgun, in raiding his almond orchard. This risk is the more deplorable when taken, as it often is, with an abundance of acorns easily accessible. The truth is I am really disturbed over this conduct of theirs. I would go to considerable trouble to warn the birds if they could understand me and would heed my warning.

A noteworthy point about these and other kinds of unfortunate or maladaptive performances by the birds is that their inability to handle the nuts with their wings is not involved. So far as their "beaking" (instead of "handling") the nuts is concerned they could do the right or safe thing as well as the wrong and dangerous thing.

The long and short of the matter is that the beggarly development of the new brain proportionately to the rest of the brain in woodpeckers as in all other birds is a dreadful handicap to them when situations are met that call for choice and decision as between particular acts and ends. Any hole in wood about the size of an acorn seems to look to these woodpeckers like a proper receptacle for a nut, no question being raised as to where the hole may lead from the standpoint of the recovery of the nut at some future time. The brain-mind endowment of the birds is sufficient to make them aware that acorns will contribute to their later as well as to their present state of existence. But it is not sufficient to make them aware of many of the conditions upon which the later availability of the nuts depends. Turn now to the Indians.

So far as recognizing the sustentative quality of the acorns is concerned, these humans would not appear to differ greatly in brain-mind endowment, just as they do not differ in digestive and assimilative endowment, from the woodpeckers.

Both obviously trust implicitly, on the strength of much experience, in the sustentative quality of the nuts. Undoubtedly the fact that the birds eat the nuts with no sort of culinary preparation, while the Indians put them through quite elaborate preparation, has some mental influence. But that the vital nutritive and biochemical significance is fundamentally alike for both, is undoubted. When it comes to the conditions upon which the later availability of the nuts depends, the difference between the two groups is enormous—as shown, for one thing, by what the Indians do in storing the nuts with reference to assuring their later availability, and to preparing them as food. In the first place they would never deliberately put their acorns in places entirely inaccessible to them—as we have noted the birds do rather often.

Then the bins, or granaries constructed of sticks, brush, grass, etc., by some of the Indian tribes for storing, simple and crude though they are, are truly designed to keep the stores dry and in some measure safe from predatory animals.

All this involves correlated brain-hand activity of no mean order. The equipment required for much of the action involved is such as to make it available for many other kinds of action to many other ends.

We may now turn to the previous question about my humble self and my ability to instruct the birds how to improve their work to their advantage, even though my work and my advantage were not involved—at least in any direct way. Again how is it that I could instruct the Indians on ways of improving their work of harvesting and storing acorns and of using them for food even though my own food needs were not at all involved? How is it that I cogitate for hours over this general problem and try hard and long to write about it in a fashion that will help to clarify my own cogitation and that of others should they be interested in such matters and happen to read what I write?

The question about helping the Indians in the various aspects of their acorn business can be partially answered with ease. Whatever is at my command but not at theirs through the industrial arts, invention, scientific discovery, and so on, is unquestionably first and foremost of head-and-hand activities that were at their command originally but have since developed in our civilization far beyond their original status. Whatever improved methods of harvesting, building, dish-making, grinding, cooking and food-serving I and my fellow immigrants could teach the native residents, these were unquestionably potential in their own simple and crude harvesting, storage-place constructing, basket-weaving, mortar-making, water-using, fire-starting-and using, spoon-making and feeding. Such unquestionable potentiality is proved by the fact that once shown how to do these things, modernly, the Indians do them sometimes quite as well, sometimes not quite as well, but sometimes rather better than we highly cultured newcomers can do them.

In other words, the question that now confronts me is: How is it that I am so vastly better off in my way of life as to food than are either the California woodpeckers or the California Indians?

As for the woodpeckers the answer is, as this whole presentation makes clear, because my sensori-motor equipment, represented especially by my brain-hands combination, is so vastly better fitted than is that of the birds for dealing with the general food problem.

But when it comes to the portions of the question about the Indians not included in the easy answer as above indicated, serious difficulties loom up. These may be more sharply stated as follows: How is it that although my sensori-motor equipment, also represented especially by my brain-hands combination, is little if any superior to that possessed by the Indians, nevertheless I (with my cultured group) actually do surpass the

Indians enormously in dealing with the food problem.

The size of the debt we humans to-day owe our ancestors in the earliest stages of human evolution is measurable only with reference to our valuation of our own lives at our present evolutional level, physical and cultural. For included in that debt is not merely the basic stages and elements of our culture, but the basic stages and elements of our sensori-motor equipment for performing the activities on which our cultural evolution depends.

Not many aspects of the problem of mankind are found to surpass in importance and difficulty that here indicated, once serious effort is made to deal with the complete reality of *Homo sapiens* in accordance with the Darwinian principle of descent with modification (evolution). As might be expected, anthropologists seem to have felt the problem with special concreteness. One of them has expressed it in striking epigrammatic fashion: . . . "even now nobody knows whether man's brain is so large because he is so intelligent or whether he is so intelligent because his brain is so large."[5]

One cardinal aim of this article is to show that we moderns are not, or need not be, so much in the dark on this matter as such utterances indicate. If "intelligent" in such a context be viewed as a descriptive term for a quality of an individual, which quality depends on the functioning of its parts, then such an antithesis as that implied by the epigram does not exist. The sentence is really meaningless. Neither in biotic metabolism nor logic can an organ or its function exist, strictly speaking, the one *before* the other.

That such a view of "intelligent" is implied by this entire discussion of mine can, I trust, not be missed by any reader. According to my view for an individual animal, a woodpecker, an Indian or myself, for example, to be intelligent is to use its entire sensori-motor equipment (of which the brain-hand combination is of first importance) so as to secure its continued existence and that in the highest measure possible for the individual itself and as a member of its species and, generally, for its particular group.

By approaching the whole vast subject from the side of natural history as Mr. Darwin conceived natural history, and from the view-point of the organismal conception as it is being developed in present-day zoology especially, it is possible, I believe, to go a long way toward solving the puzzle.

On the basis of the fundamental truth contained in the maxim "self-preservation is the first law of life" it is now recognizable that awareness by an individual animal of the advantage of avoiding particular acts that might result in its own death or serious injury, is the initial step toward modifying the kind of selection called natural by Darwin into what is familiar to almost everybody as conscious, rational or (in Darwinian terminology) artificial selection. Artificial selection may be called natural selection raised to the *n*th degree of effectiveness.

Another expression for much the same thing is possible by utilizing the phrase trial and error, especially familiar to zoologists: Artificial selection is nature's method of increasing success to a maximum and reducing error to a minimum, in individual activity.

In these few brazenly dogmatic sentences I have tried to cram the essence of much that is contained in the two books mentioned on the first page of this article.

Nearly central to the book entitled "Nature" is a discussion of something like 70,000 words of the problem of getting and using natural knowledge (epistemology of traditional philosophy) approached from the side of natural history and the organismal conception. The undertaking follows the lead of Mr. Darwin in his approach to the subject of the moral sense or conscience, from the side of natural history. Still more fundamentally, it follows Darwin's lead in conceiving man as natural in every quality of his being in the same sense that he is natural in any other quality of his being.

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[5] E. A. Hooton, "Up from the Ape," p. 141, 1935.

This insight by Darwin, although only partial and dim in some of its aspects, marks him as indeed an "intellectual colossus"[5] and places him among the very foremost persons of all time who have contributed to the carrying out of the Delphic Oracle's command, Know thyself. Whether "anthropology is the child of Darwin," as viewed by some anthropologists,[6] I venture no opinion, not being an anthropologist myself. I do not hesitate, however, to say as a zoologist that until man could be viewed as natural in the same sense that every other zoological species is natural, no trustworthy general knowledge, much less understanding and theory, of man was possible.

So long as men (the males of the species, I mean; what I am about to say applies less to the females) consider themselves as *not* natural, *i.e.*, as supernatural, in certain of their qualities while natural in other qualities; or consider that certain individuals among them are wholly supernatural, they are in the same boat with those "savages" and culturally backward peoples (the Hindus, for example) who regard certain sub-human animals as sacred and proper objects of worships. Here is another of the almost endlessly varied outcrops of what seems to have been one of the earliest efforts of the human species at theorizing about its own nature, namely, the effort that has produced the familiar doctrine of "mind or soul *versus* body."

One of the foremost results of the epistemological enterprise referred to is highly remedial for this tragically disintegrative conception of humans and other kinds of animals. This result depends largely on recognizing that all the most definitive qualities of humans—those powers and activities of theirs named thinking, reasoning and understanding, are inseparable (as far as all trustworthy evidence is concerned) from certain qualities manifested by all bodies known as living from bacteria to oaks and redwoods, and from amoebae to woodpeckers and my precious self.

Here, then, is what the "mutually interpretative relation between human and avian natural history" comes to as exemplified by the couplet of myself and the California woodpeckers: My wonderful superiority over them in anatomical-physiological equipment for acting for the welfare, on the whole, of myself and of my kind makes me also an illustration of the classificatory view expressed by Mr. Darwin that the quality by which the species, *Homo sapiens*, is most distinctly differentiated from all other animal species is the "moral sense or conscience."

However, this wonderful anatomical-physiological superiority of mine for acting adaptively entitles me to no such ranking in the moral realm unless I use the equipment in accordance with its own nature, namely, that of acting for my own welfare and that of my kind to the fullest extent possible in every situation in which I act consciously at all.

Exceedingly greater personal responsibility for my own acts as compared with that of any bird for its acts may be compendiumized as the sum and substance of this essay.

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[6] R. R. Marett, "Anthropology," p. 8.

THE FARADAY-WHEWELL CORRESPONDENCE CONCERNING ELECTRO-CHEMICAL TERMS

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THE terms *electrode, anode, cathode, anion, cation, electrolyte,* etc., have now entered on their second century of usefulness. They have met the test of time and constitute a permanent monument to the good judgment and acumen of their genitors. To whom is the world really indebted for these excellent words, which even laymen are finding indispensable? Should the entire credit go to Faraday, who was the first to use these terms, some partly his own invention, others coined at his request? A large share of the honor indubitably belongs to Whewell, the competent counselor to whom Faraday appealed for advice and suggestions when he found it impossible to expound his electrochemical researches in the existing vocabulary.

William Whewell, D.D. (1794–1866), one of the most brilliant men that Cambridge has produced, spent his entire career in the service of this university.[1] As fellow, professor (mineralogy, 1828–33; moral philosophy, 1838–55) and master of Trinity College (1841–66) he exerted a decided influence, both by example and legislation, in the strengthening of science teaching. Trained initially as a mathematician, his mind was too versatile to be kept within the bounds of a single field, and he shifted part of his energy to science, especially physics, but in science he was an able critic rather than an originator. In middle life he turned his attention particularly to philosophy and to history of science, "not that I do not still love science, but in it I have done all that I can." He is now best known for his elaborate historical reviews[2] of the processes of generalization.

In these volumes he exhibited a wideness of knowledge that at the time placed him in a class almost by himself. John Herschell was probably not far from the truth in his eulogy: "A more wonderful variety and amount of knowledge in almost every department of human inquiry was perhaps never in the same interval of time accumulated by any man." The quip, "science is his forte and omniscience is his foible," was applauded by those who thought that he had spread his talents too thin, but Lyell saw with a clearer eye when (1837) he wrote to Whewell:

> There was a time when I used to regret that you had not concentrated your powers on some one department of physical science and become a giant in that, or at least that you had been satisfied with some two or three of the Arts and Sciences, but I have for some years come round to the belief that you have been exercising the

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[1] For biographical material see I. Todhunter, "William Whewell, an Account of his Writings, with Selections from his Literary and Scientific Correspondence," 1876; Mrs. Stair Douglas, "The Life and Selections from the Correspondence of William Whewell," 1881; L. Stephen, "Dictionary of National Biography," Vol. 60, p. 454, 1899.

[2] (a) "The History of the Inductive Sciences from the Earliest to the Present Time." 3 vols., 1837. New edition, revised and continued, 1847; (b) "The Philosophy of the Inductive Sciences founded upon their History," 2 vols., 1840. A new edition, with corrections and additions, 1847.

> calling for which Nature intended you, and for which she gave you strength and genius, and that you have given a greater impulse to the advancement of science among us by being a Universalist, and by mastering so much of Chemistry, Mineralogy, Astronomy, Geology, and other branches, than you would have done if restricted to the perfecting of any one alone.

During his student days, Whewell showed marked ability in Latin and Greek and in his early years planned to devote considerable attention to linguistics. Even after his mathematical and scientific labors checked this youthful intention, he continued his deep interest in etymological studies and speculations. He wrote extensively on the language of science.[3] He was acquainted with many of the scientific leaders of the day, and to them he made no secret of his passion for correct usage of classic roots in the construction of new scientific terms. He freely offered his services as consultant and critic in such matters, and his expert knowledge was used by some of the most eminent of his scientific contemporaries. Bell, Lubbock, Lyell, Murchison, Owen, adopted names that had been suggested by him or that had been submitted for his appraisal.

The chief beneficiary of Whewell's terminological cooperation was Faraday. Elected to the Royal Society in 1824, he there came to know Whewell (elected in 1820), and as his own formal schooling had been so scanty, ending when he was thirteen, he doubtless was impressed by the breadth of the culture possessed by the Cambridge savant. On the other side, Whewell could not but admire Faraday's scientific powers, and a friendship was established between these two whose basic training had been so dissimilar.

Electricity was always of great interest to Faraday, and he worked on it intermittently even during that period, 1816–1831, which saw him develop into a chemical investigator of the first rank. He discovered electromagnetic induction in August, 1831. This was the turning point in his career, and now began that series of celebrated studies that were recorded in the successive series of his "Experimental Researches in Electricity and Magnetism." Novel results required new terms for their exposition, and as early as November 29, 1831, in a letter[4] to Richard Phillips, the chemist, Faraday tells of a new term: "*The Electrotonic State.* What do you think of that? Am I not a bold man, ignorant as I am to coin words but I have consulted the scholars." When he put this term into print, he did not disclose his consultants: "I have after advising with several learned friends ventured to designate it as the *electrotonic* state."

This first instance of the introduction of a new term by Faraday is characterized by two features that accompany all the subsequent examples: (1) He did not venture to proceed independently in the coining of words; (2) he did not publicly name the philological experts from whom he sought counsel and suggestions.

Although Whewell probably was not one of these "learned friends," the two were by this time on an easy footing with each other and Faraday knew of Whewell's expertness in such matters. Only a few months before, on February 21, 1831, he had written to Whewell concerning the use of scientific language:

> I cannot help thinking it is a most unfortunate thing that men who as experimentalists and philosophers are the most fitted to advance the general cause of science and knowledge should by the promulgation of their own theoretical views under the form of nomenclative notation or scale actually retard its progress. It would not be of so much consequence if it was only

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[3] See, for example, his "Aphorisms concerning the Language of Science" in his "Philosophy," vol. 2, 1847, p. 479.

[4] S. P. Thompson, "Michael Faraday, His Life and Work," p. 116. 1898.

> theory and hypothesis which they thus treated, but they put facts or the current coin of science into the same limited circulation when they describe them in such a way that the initiate only can read them.[5]

Faraday's researches soon led him into the long-standing problem as to whether the electricity derived from different sources is identical. Chemical action was an obvious test, and this line of attack took him directly into a study of conduction of solutions and fused compounds, its mechanism, its constant association with decomposition, the liberation of the decomposition products at the poles rather than in the body of the conducting liquid, the relation of the amount of chemical action and the quantity of electricity passed, etc. His success in the solving of these problems is well known, but only cursory attention has been given to his equal success in inspiring the construction of a satisfactory terminology when he found no words in the language with which to clearly express his thoughts and findings.

Chemical decomposition accompanying electrical conduction was no new subject to one who had been so closely associated with Davy, but Faraday soon saw that the prevailing theory was untenable.

> It was generally assumed that the wires by which the current entered and left the decomposing substance acted like positively and negatively charged conductors, and by their electrical attraction tore the reluctant atoms from the compound molecule. Faraday saw that this hypothesis would not work. He knew that by suitable arrangements the strongest chemical compounds could be broken up by the feeblest currents. It would follow, therefore, on the old hypothesis that the feeblest current was stronger than a powerful chemical attraction. This seemed to Faraday very improbable. Before pushing his experiments further Faraday felt the necessity of clearing the ground of the relics of the older theory by giving new names to the various phenomena. He appreciated fully the tyranny that mere names can wield over the human intellect, and determined to free at least this branch of science from their baleful influence by a nomenclature which should imply nothing beyond what had been experimentally confirmed.[6]

The word *pole,* from its association with the magnet, was barnacled with meanings and implications opposed to what he believed: "the determining force is *not* at the poles but *within* the body," and so he replaced this misleading term by one more consistent with this belief that: "the poles are merely the surfaces or doors by which the electricity enters into or passes out of the substance suffering decomposition." *Electrode* (Gr. electron + *hodos* = way) appears for the first time on December 17, 1833. The Diary[7] (§ 1173) for that day records that when he passed a current through "fuzed Proto chloride of Tin" he observed that "Deuto chloride of tin passed off from the P. Electrode and Metallic tin was rendered at the N. Electrode." Later that day (§ 1175) he wrote: "Hence 1.76 of tin had been electrochemically evolved at the *exode* and of course a corresponding proportion of chlorine at the *cisode* . . ."[8]

He also required a word to express "those bodies which can pass to the electrodes." The entry for December 19 states: "When a body of known composition is decomposed directly by the Electric current, may conclude that its proximate principles are *Electrobeids.*" This term (probably derived from the Greek baino = I go) had obvious disadvantages and was soon replaced by *zetode,* which in turn gave way to *ion.*

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[5] The Council of Trinity College has generously given leave to publish here for the first time extracts from the Faraday-Whewell correspondence. Other letters that have already appeared in print are reprinted here in order to complete the picture.

[6] J. A. Crowther, "The Life and Discoveries of Michael Faraday," p. 39 *ff*. 1918.

[7] "Faraday's Diary. Being the various Philosophical Notes of Experimental Investigation made by Michael Faraday during the years 1820–1862." Bell, London, 7 vols., 1932–36. Volume II, 1932, covers the period from August 25, 1832 to February 29, 1936, §§ 1–3025.

[8] *Cisode* is given in §§ 1175, 1195, 1325, 1591, 1738, but nowhere else. The Faraday-Whewell letters contain in its place *eisode*. Faraday's "c" and "e" are easily mistaken for one another. Thomas Martin, editor of the Diary, after a special examination of this Faraday manuscript, insists that Faraday wrote and intended to write *cisode*.

These, together with other *mots d'occasion,* were given a public trial on January 23, 1834, when Faraday read before the Royal Society the first part of his now famous paper,[9] in which he summarized all his previous work on electrochemistry. He began:

> The theory which I believe to be a true expression of the facts of electrochemical decomposition —is so much at variance with those previously advanced, that I find the greatest difficulty in stating results, as I think, correctly, whilst limited to the use of terms which are current with a certain accepted meaning—To avoid, therefore, confusion and circumlocution, and for the sake of greater precision of expression than I can otherwise obtain, I have deliberately considered the subject with two friends, and with their assistance and concurrence in framing them, I purpose henceforward using certain other terms, which I will now define.

Then follow definitions and derivations of *electrode, anode, cathode, electrolyte, electrolyzed, anion, cation,* . . .

> These terms being once well defined, will, I hope, in their use enable me to avoid much periphrasis and ambiguity of expression. I do not mean to press them into service more frequently than will be required, for I am fully aware that names are one thing and science another.

No one, and least of all Faraday, has given a clear history of the genesis of this terminology. His statement, "I have deliberately considered the subject with two friends," is his only public acknowledgment of indebtedness; he nowhere tells who his advisers were.[10]

The confusion and uncertainty arises from the following sequence of events. Faraday, in his paper of January 23, presented a set of new terms, which probably had been concocted in somewhat of a rush. After due reflection and possibly after consultation, it became apparent that some of these terms did not meet the requirements, and wishing further expert advice and fresh intelligence he decided to place his problem before the person generally recognized as the best authority on scientific language. Whewell, who had heard the paper, gladly gave the matter the attention it deserved, and when in May, the proof sheets came to Faraday for correction, he substituted Whewell's proposals for some of the terms he had used in January. Consequently, *electrobeid, exode, eisode* (or *cisode*) and probably others, never appeared in the published paper. The only printed evidence of the alterations in the terminology was the footnote, "Since this paper was read, I have changed some of the terms which were first proposed that I might employ only such as were at the same time simple in their nature, clear in their reference, and free from hypothesis."[11]

The electrochemical terminology for the most part was evolved during the period between the reading and publication of the paper, a fact that hitherto has either been unknown or disregarded, with the result that Whewell has never been given adequate credit for the predominant part he played in the coinage of these new terms.[12]

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[9] Philosophical Transactions of the Royal Society of London. For the year 1834, Part I: Experimental Researches in Electricity. Seventh Series. By Michael Faraday. Received January 9, Read January 23, February 6 and 13, 1834, p. 77, On Electrochemical Decomposition, continued IV.

[10] The letters mention Mr. Willis and Dr. Nichols. Though Faraday's spelling of names can not be trusted, (*e.g.*, Nicol, the inventor of the prism, appears in the Diary also as Nicholl, Nichol) no men of science of these or similar names seem to fit the rôle of advisers in his introduction of new terms.

[11] The authorities of the Royal Society and of the Royal Institution, at the writers' request, searched their archives for the original manuscript and the corrected proof sheets. No trace of either was found, and Faraday probably destroyed the originals after he had made the substitutions and alterations. The terms he discarded can now only be inferred from the Diary and the letters.

He not only made suggestions but also argued Faraday into accepting terms whose excellence has now been amply demonstrated. Nowhere has Whewell put forth any claims for any part of the honor; on the contrary, he sedulously fostered the belief that Faraday alone was responsible for these terms.[13]

About 65 items of the Faraday-Whewell correspondence are in the library of Trinity College, Cambridge, including letters dealing with the genesis of the electrochemical terminology. Some of these have been published, but others, equally important to this present discussion, have never appeared in print. The letters tell the story and need no comment. Faraday's punctuation is almost nil, and there is little consistency in his use of capitals.

I

Faraday to Whewell

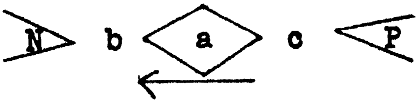
Royal Institution
24th April, 1834

My dear Sir

I am in a trouble which when it occurs at Cambridge is I understand referred by everybody in the University to you for removal and I am encouraged by the remembrance of your kindness and on Mr. Willis' suggestion to apply to you also But I should tell you how I stand in the matter.

I wanted some new names to express my facts in Electrical science without involving more theory than I could help & applied to a friend Dr. Nicholl who has given me some that I intend to adopt for instance a body decomposable by the passage of the electric current I call an "*electrolyte*" and instead of saying that water is *electrochemically decomposed* I say it is "*electrolysed*" The intensity above which a body is decomposed beneath which it conducts without decomposition I call the "Electrolytic intensity" &c &c. What have been called the poles of the battery I call the *electrodes* They are not merely surfaces of metal but even of *water* and *air* to which the term poles could hardly apply without receiving a new sense. *Electrolytes* must consist of two parts which during *electrolysation* are determined the one in one direction the other in the other toward the electrodes or poles where they are evolved These evolved substances I call *zetodes* which are therefore the direct constitutents of electrolites.(*sic*)

All these terms I am satisfied with but not with two others which I have used thus far. It is essential to me to have the power of referring to the two surfaces of a decomposable body by which the current enters into and passes out of it without at the same time referring to the electrodes. Thus let *a* be a decomposable body & P & N the pos & neg poles which may or may not be in contact with *a* at the points *b.c* and shall yet transmit the electricity which passes through *a*



Admitting the usual mode of expression and talking of a current of Electricity proceeding from the positive pole P through *a* to the negative pole N my friend suggests and I have used the terms *eisode* for c and *exode* for b, the points where the *Zetodes* are rendered and a zetode going to c I have called a *zeteisode* and another going to b a *zetexode*

But the idea of a current especially of *one* current is a very clumsy and hypothetical view of the state of Electrical forces under the circumstances The idea of *two* currents seems to me more suspicious and I have little doubt that the present view of electric currents and the notions by which we try to conceive of them will soon pass away and I want therefore names by which I can refer to *c* & *b* without involving any theory of the nature of electricity. In searching for a reference on which to found these I can think of nothing but the globe as a magnetic body If we admit the magnetism of the sphere as due to electric currents running in lines of latitude their course must be according to our present modes of expression from East to West and if a portion of water under decomposition by an electric current be placed so that

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[12] See, for instance, J. Tyndall, "Faraday as a Discoverer," 1868, p. 54; J. Gladstone, "Michael Faraday," n.d., p. 181; H. Hartley, *Chem. News*, 144: 410, 1932; Thompson, *op. cit.*, p. 143.

[13] "History," 1847. Vol. 3, p. 184; *idem*, "Philosophy," 1847. Vol. 1, p. 52; Vol. 2, pp. 587, 547.

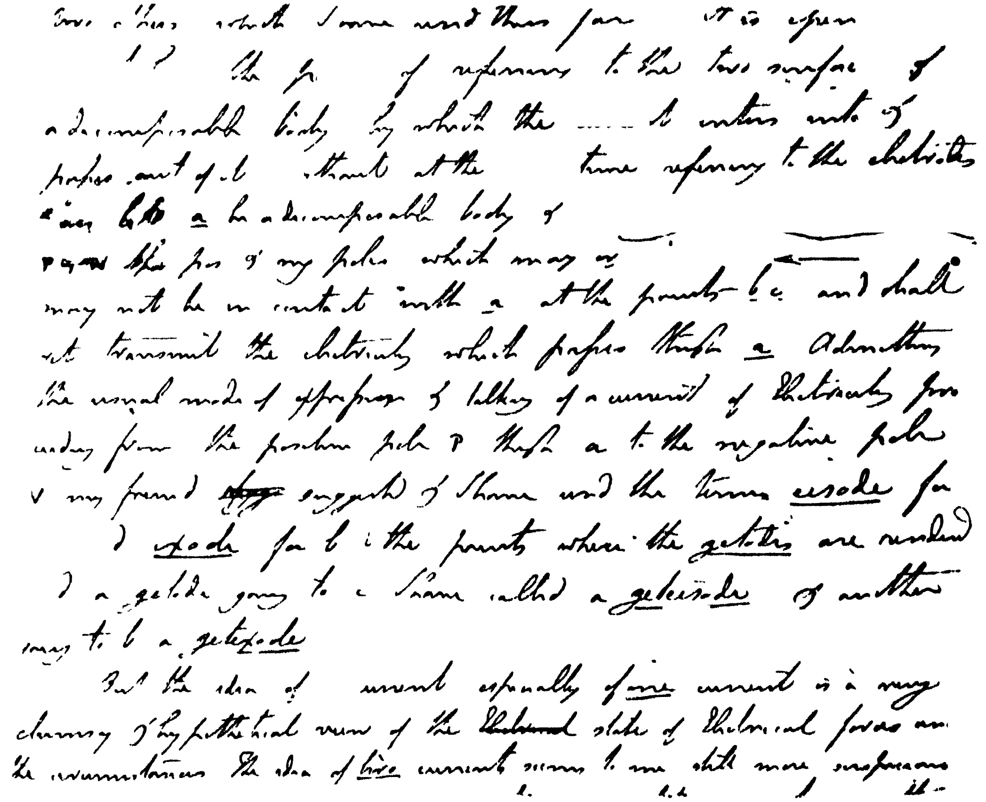

FIG. A. PORTION OF FARADAY'S LETTER, APRIL 24, 1834.
NOTE HIS ORIGINAL TERMS: EISODE, EXODE, ZETEISODE, ZETEXODE.

the current through it be parallel to that circulating round the earth then the oxygen will be rendered toward the east as at *c* in the figure and the hydrogen toward the west as at *b* in the figure I think therefore that if I were to call c the *east-ode* and *b* the *west-ode* I should express these points by reference to a standard which whatever changes take place in our theories or knowledge of electricity will still have the same relation But Eastode or Westode or oriode and occiode are names which a scholar would not suffer I understand for a moment and *anatalode* and *dysiode* have been offered to me instead.

Now you can help me out to two good names not depending upon the idea of a current in *one direction only* or upon positive or negative and to which I may add the prefixes zet or zeto so as to express the class to which any particular *setode* may belong.

I am making very free with you if you feel inclined to help me I shall be very much obliged and if not may (*sic*) no ceremony in saying that you cannot assist me.

II

Whewell to Faraday[14]

Trinity College, Cambridge.
April 25, 1834.

My Dear Sir,

I was glad on several accounts to receive your letter. I had the pleasure of being present at the R. S. at the reading of your paper, in which you introduced some of the terms which you mention, and I was rejoiced to hear them, for I saw, or thought I saw, that these novelties had been forced upon you by the novelty of extent and the new relations of your views. In cases where such causes operate, new terms inevitably arise, and it is very fortunate when those, upon whom the introduction of these devolves, look forward as carefully as you do to the general bearing and future prospects of the subject; and it is an additional advantage when they humour philologists so far as to avoid gross incongruities of language. I was well satisfied with most of the terms that you mention; and shall be glad and gratified to assist in freeing them from false assumptions and implications, as well as from philological monstrosities.

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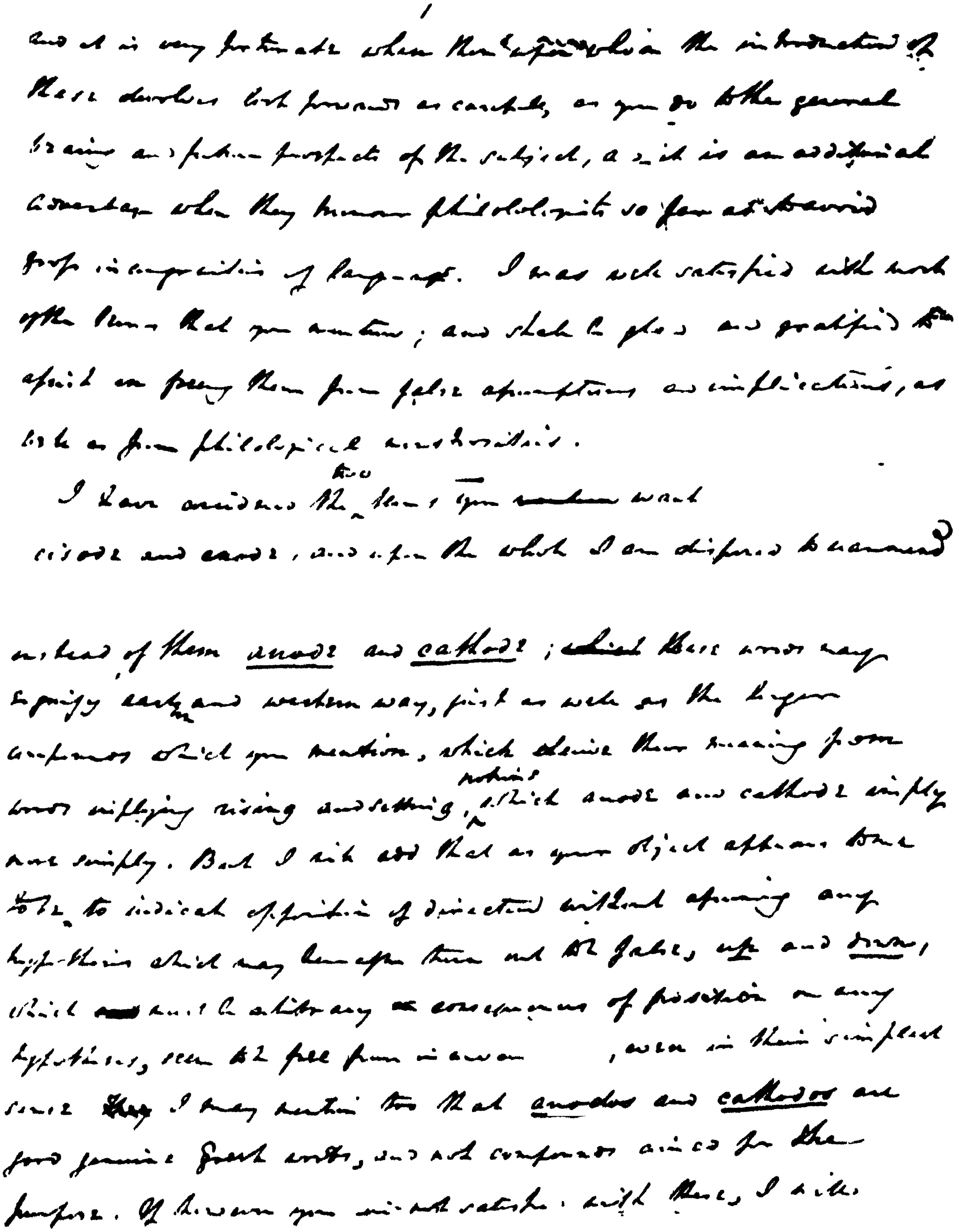
[14] I. Todhunter, *op. cit.*, Vol. 2, p. 175.

I have considered the two terms you want to substitute for *eisode* and *exode*, and upon the whole I am disposed to recommend instead of them *anode* and *cathode*. These words may signify *eastern* and *western* way, just as well as the longer compounds which you mention, which derive their meaning from words implying rising and setting, notions which anode and cathode imply more simply. But I will add that, as your object appears to me to be to indicate opposition



and it is very fortunate when those [illegible] in the introduction of
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instead of them anode and cathode; ~~which~~ these words may
signify eastern and western way, just as well as the longer
compounds which you mention, which derive their meaning from
words implying rising and setting, notions which anode and cathode imply
more simply. But I will add that as your object appears to me
to be to indicate opposition of direction without assuming any
hypothesis which may hereafter turn out to be false, up and down,
which must be arbitrary consequences of position on any
hypothesis, seem to be free from an error , even in their simplest
sense. ~~They~~ I may mention too that anodos and cathodos are
good genuine Greek words, and not compounds coined for the
purpose. If however you are not satisfied with these, I will

FIG. B. EXCERPT FROM WHEWELL'S LETTER OF APRIL 25,
IN WHICH THERE APPEARS FOR THE FIRST TIME *anode* AND *cathode*.

of direction without assuming any hypothesis which may hereafter turn out to be false, *up* and *down*, which must be arbitrary consequences of position on any hypothesis, seem to be free from inconvenience even in their simplest sense. I may mention too that *anodos* and *cathodos* are good genuine Greek words, and not compounds coined for the purpose. If however you are not satisfied with these, I will propose to you one or two other pairs. For instance, *dexiode* and *sceode* (*skaiode* if you prefer it) may be used to indicate *east* and *west*, agreeably to Greek notions and usages, though their original meaning would be *right* and *left;* but I should say in this case also, that right and left, as it cannot be interpreted to imply a false theory, any more than east and west, would be blameless for your object. Another pair, *orthode* and *anthode*, which mean *direct* and *opposite* way might be employed; but I allow that in these you come nearer to an implied theory. Upon the whole I think *anode* and *cathode* much the best.

I have already said that I liked most of your new words very well, but there is one which I should be disposed to except from this praise; I mean *zetode.* My objections are these. This word being grouped with others of the same termination might be expected to indicate a modification of electr*ode*, as eis*ode*, and ex*ode*, or an*ode* and cath*ode* do. Instead of this, it means a notion altogether heterogeneous to these, and the *ode* is here the object of a verb *zete*, contrary to the analogy of all the other words. It appears to me that, as what you mean is an element, all that you want is some word which implies an element of a composition, taking a *new* word, however, in order that it may be recollected that the decomposition of which you speak is of a peculiar kind, namely, *electrolytical* decomposition. Perhaps the Greek word *stecheon* (or *stoicheion*) would answer the purpose. It has already a place in our scientific language in the term *stoicheiometry,* and has also this analogy in its favour, that whereas your other words in *ode* mean *ways*, this word stecheon is derived from a word which signifies to *go in a row.* The elements or zetodes are two things which *go* or *seek to go* opposite ways. I might add that, if you want a word which has a reference to your other terms, the reference must be to the process of decomposition by which these elements are obtained. You might call your zetode, an *electrostecheon*, especially if you had occasion to distinguish these elements obtained by *electrolytical* processes from others obtained by *chemolytical* processes, that is, the common analysis effected by the play of affinities. Elements obtained in the latter way might be called *chemostecheons* in opposition to *electrostecheon.* But I am afraid I am here venturing beyond my commission and out of my depth; and you must judge whether your stecheons or zetodes, or whatever they are to be, are likely to require the indication of such relations. If you were to take anode and cathode and adopt stecheon, I think *anastecheon* and *catastecheon* might indicate the two *stecheons.* If you stick to zetode, *anazetode* and *catazetode* would be the proper terms; but perhaps *zetanode* and *zetocathode* would be more analogous to zetode, which is a word that, as I have said, I do not much like.

My letter is become so long that I will recapitulate: *anode, cathode, zetanode, zetocathode* fulfil your requisitions; *anode, cathode, anastecheon, catastecheon* are what I prefer.

With great interest in your speculations, and best wishes,

III

Faraday to Whewell

R Institution
3 May 1834

My dear Sir·

I have waited very impatiently for a proof of my paper that I might send it to you with my letter of thanks for your kindness But I have invoked by that a charge of unthankfulness toward you which however I assure you I do not deserve

All your names I and my friend approve of or nearly all as to sense and expression but I am frightened by their length and sound when compounded. As you will see I have taken *dexiode* and *skaiode* because they agree best with my natural standard East and West I like anode and cathode better as to sound but all to whom I have shown them have supposed at first that by *anode* I meant *no way*

Then *Stechion* I have taken although I would rather not have had the hard sound of *ch* here especially as we have similar sound in both the former words. But when we come to combine it with the two former as *dexio-stechion* and *skaio-stechion* especially the latter I am afraid it becomes inadmissible simply from its length and sound forbidding its familiar use. I think you will agree with me that I had better not form a new word than form one which is not likely to enter into common use.

It is possible that by this time some other shorter word may have occurred for *stechion* if so will you favor me with it If not I think I must strike out the two compounds above and express my meaning without the use of names for the two classes of stechions though they are very very much wanted.

It was the shortness and euphony of zeteisode and zetexode which were their strong recommendations to me.

P.S. Can you give me at the bottom of the pages the Greek derivations &c &c that when you return me the leaves I may have them right for the printer They are of course uncorrected at present.

IV

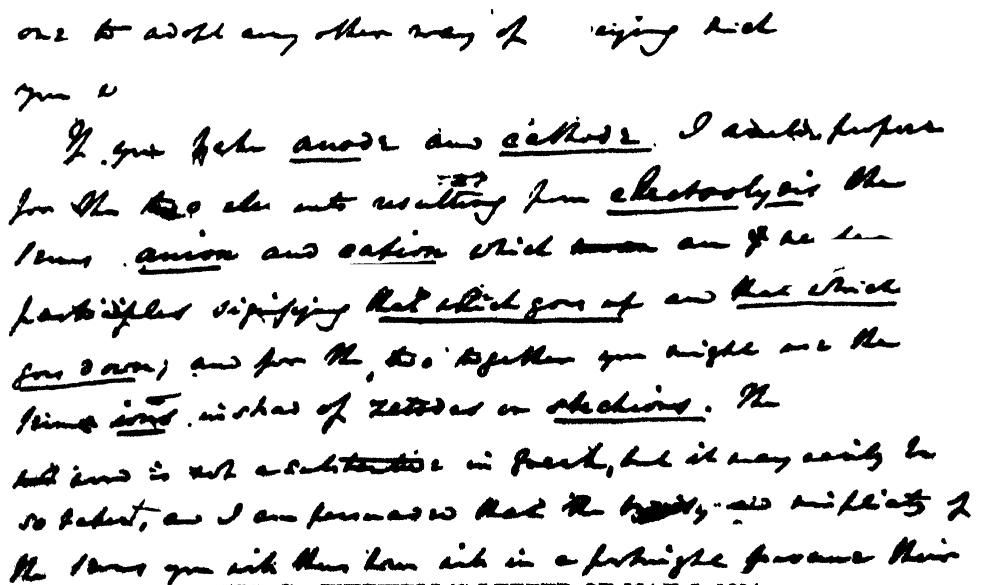
Whewell to Faraday[15]

Trinity Coll. Cambridge
May 5, 1834.

My Dear Sir,

I quite agree with you that *stechion* or *stechеon* is an awkward word both from its length and from the letters of which it is composed, and I am very desirous that you should have a better for your purpose. I think I can suggest one, but previous to doing this, I would beg you to reconsider the suggestion of *anode* and *cathode* which I offered before. It is very obvious that these words are much simpler than those in your proof sheet, and the advantage of simplicity will be felt very strongly when the words are once firmly established, as by your paper I do not in the least degree doubt that they will be. As to the objection to *anode*, I do not think it is worth hesitating about. *Anodos* and *cathodos* do really mean in Greek a *way up* and a *way down;* and *anodos* does not mean, and cannot mean, according to the analogy of the Greek language, *no way*. It is true that the prefix *an*, put before *adjectives* beginning with a vowel, gives a negative signification, but not to substantives, except through the medium of adjectives. *Anarchos* means *without government*, and hence *anarchia*, *anarchy*, means the *absence of government:* but *anodos* does not and cannot mean the *absence of way*. And if it did mean this as well as a *way up*, it would not cease to mean the latter also; and when introduced in company with *cathodos*, nobody who has any tinge of Greek could fail to perceive the meaning at once. The notion of *anodos* meaning *no way* could only suggest itself to persons unfamiliar with Greek, and accidentally acquainted with some English words in which the negative particle is so employed; and those persons who have taken up this notion must have overlooked the very different meaning of negatives applied to substantives and adjectives. Prepositions are so very much the simplest and most decisive way of expressing opposition of other relations, that it would require some very strong arguments to induce one to adopt any other way of conveying such relations as you want to indicate.

If you take *anode* and *cathode*, I would propose for the two elements resulting from *electrolysis* the terms *anion* and *cation*, which are neuter participles signifying *that which goes up*, and *that which goes down;* and for the two to-



one to adopt any other way of conveying such
you w

If you take anode and cathode, I would propose
for the two elements resulting from electrolysis the
terms anion and cation which are neuter
participles signifying that which goes up and that which
goes down; and for the two together you might use the
terms ions instead of zetodes or stechions. The
word is not a substantive in Greek, but it may easily be
so taken, and I am persuaded that the brevity and simplicity of
the terms you will thus have will in a fortnight procure their

FIG. C. WHEWELL'S LETTER OF MAY 5, 1834.

THE PORTION REPRODUCED HERE CONTAINS HIS FIRST PROPOSAL OF *anion* AND *cation*.

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[15] Todhunter, *op. cit.*, Vol. 2, p. 181.

gether you might use the term *ions*,[16] instead of *zetodes* or *stechions*. The word is not a substantive in Greek, but it may easily be so taken, and I am persuaded that the brevity and simplicity of the terms you will thus have will in a fortnight procure their universal acceptation. The *anion* is that which goes to the *anode*, the *cation* is that which goes to the *cathode*. The *th* in the latter word arises from the aspirate in *hodos* (way), and therefore is not to be introduced in cases where the second term has not an aspirate, as *ion* has not.

Your passages would then stand thus:

"We purpose calling that toward the east the *anode* (ἀνά, upwards, ὁδός, a way; the way which the sun rises), and that towards the west *cathode* . . . (κατά, downwards, ὁδός, a way; the way which the sun sets). I purpose to distinguish these bodies by calling those *anions* (ἀνιόν, that which goes up (neuter participle) which go to the *anode* of the decomposing body, and those passing to the *cathode*, *cations* (κατιόν, that which goes down)." And when I have occasion to speak of these together I shall call them *ions*.

I am so fully persuaded that these terms are from their simplicity preferable to those you have printed, that I shall think it a misfortune to science if you retain the latter. If, however, you still adhere to *dexio* and *scaio*, I am puzzled to combine these with *ion* without so much coalition of vowels as will startle your readers. I put at the bottom of the page the explanation, if you should persist in this.* I would only beg you to recollect that even violent philological anomalies are soon got over, if they are used to express important laws, as we see in the terms *endosmose* and *exosmose;* and therefore there is little reason for shrinking from objections founded in ignorance against words which are really agreeable to the best analogies. The existing notation of Chemistry owes its wide adoption and long duration to its simplicity.

I am afraid you will think I am fond of playing the critic if I make any further objections, otherwise I would observe on your Article 666, that if you are not sure that you will want such words as *astechion*, it is throwing away your authority to propose them. If what I have written does not answer your purpose, pray let me hear from you again, and believe me,

P.S. If, adopting the term *ion* for *stechion*, you do want the negative *astechion*, I do not think there will be any difficulty in devising a suitable word.

V

Whewell to Faraday[17]

Trin. Coll. Cambridge. May 6, 1834.

My dear Sir,

You will have received my letter of yesterday and perhaps will have formed your opinion of it. I still think *anode* and *cathode* the best terms beyond comparison for the two electrodes. The terms which you mention in your last show that you are come to the conviction that the essential thing is to express a *difference* and nothing more. This conviction is nearly correct, but I think one may say that it is very desirable in this case to express an *opposition*, a contrariety, as well as a difference. The terms you suggest are objectionable in not doing this. They are also objectionable it appears to me, in putting forward too ostentatiously the arbitrary nature of the difference. To talk of Alphode and Betode would give some persons the idea that you thought it absurd to pursue the philosophy of the difference of the two results, and at any rate would be thought affected by some. Voltode and Galvanode labour no less under the disadvantage of being not only entirely, but ostentatiously arbitrary with two additional disadvantages; first that it will be very difficult for anybody to recollect which is which; and next that I think you are not quite secure that further investigations may not point out some historical incongruity in this reference to Volta and Galvani. I am more and more convinced that *anode* and *cathode* are the right words; and not least, from finding that both you and Dr. Nichols are ready to take any arbitrary opposition or difference. *Ana* and *Kata* which are prepositions of the most *familiar* use in composition, which indicate *opposite* relations in space, and which yet *cannot* be interpreted as involving a theory appear to me to unite all desirable properties.

I am afraid of urging the claims of *anion* and *cation* though I should certainly take them if it were my business—that which *goes to* the *anode* and that which goes to the cathode appearing to me to be exactly what you want to say. To talk of the two as *ions* would sound a little harsh at first: it would soon be got over. But if you are afraid of this I think that *stechion*, as the accepted Greek name for element, is a very good word to adopt, and then, *anastechion* and *catastechion* are the two contrary elements, which I am sure are much better words than you can get at by using *dexio* and *scaio* or any other terms not prepositions.

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[16] Gr. ion, present participle of ieno = to go (Note by M S.).

* δεξιός on the right hand, and hence, the *east*, σκαιός on the left hand, and hence, the *west*.

[17] Diary, Vol. 2, between pp. 272–273. This letter is preserved at the Royal Institution.

I expect to be in London Friday and Saturday, and if I am I shall try to see you on one of those days and to learn what you finally select.

Without further exchange of letters, Faraday accepted the Whewellian proposals, put the new terms into the proof sheets and the printed version of his paper appeared in June or July, 1834.

VI

Faraday to Whewell

Royal Institution
15 May 1834

My dear Sir—

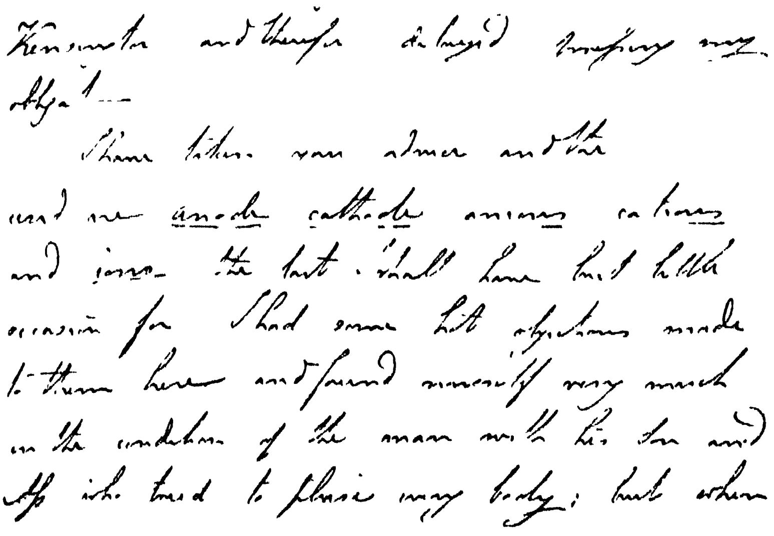
I ought before this to have thanked you for your great kindness in the matter of the names respecting which I applied to you; but I hoped to have met you last Saturday at Kensington and therefore delayed expressing my obligations.

I have taken your advice and the names used are *anode cathode anions* and *ions* the last I shall have but little occasion for. I had some hot objections made to them here and found myself very much in the condition of the man with his son and ass who tried to please every body; but when I held up the shield of your authority it was wonderful to observe how the tone of objection melted away

I am delighted with the facility of expression which the new terms give me and shall ever be your debtor for the kind assistance you have given me.

Privately, Faraday began to use the new terms at once. The Diary for May 13 refers to *ions* (§ 1754) and contains the statement: "for it is certain that when currents are formed, water is electrolyzed[18] and that oxygen is disposed of at the *anode* in the alkali and hydrogen at the cathode in the acid" (1758). Habit proved too strong when he was alone with his thoughts and he sporadically reverted to the old terms in his Diary. Such backslidings can be found up to November 6, 1835, and in fact as late as October, 1837, Whewell felt impelled to write: "As for positive and negative, I do not see why *cathodic* and *anodic* should not be used, if they will do the service you want of them."[19]

The spelling of anion and cation varied with Faraday, who at times wrote anion and cation, and likewise with Whewell, who used cation (or cathion) because: "The analogy of the Greek derivation



Kensington and therefore delayed expressing my
obligations—
I have taken your advice and the
names used are anode cathode anions cations
and ions the last I shall have but little
occasion for I had some hot objections made
to them here and found myself very much
in the condition of the man with his son and
Ass who tried to please every body; but when

FIG. D. EXCERPT FROM FARADAY'S LETTER OF MAY 15, 1834, SHOWING HIS ACCEPTANCE OF *cathode, anode, anions, cations, ions.*

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[18] ***Electrolysed*** and ***Electrolyte*** (electron + lyo = to loosen) occur in the Diary (§§ 1738, 1739) as early as April 19, 1834.—J. F. Couch, *Am. Jour. Pharm.*, 95: 806 (1923), discussed the sense in which Faraday used *electrolyte.*

[19] Thompson, *op. cit.*, p. 163.

requires *cation;* but to make the relation to *cathode* obvious to the English reader, and to avoid a violation of the habits of English pronunciation, I should prefer *cathion.*"[20] The variants kathode, kation, etc., were never used by either Faraday or Whewell.

Despite its excellence[21] and even though the terminology was adopted throughout Europe, its complete usefulness did not appear until many years after its birth. As late as 1868 Tyndall could state that while *electrolyte* and *electrolysis* had become established, *anode* and *cathode* "though frequently used, have not enjoyed the same currency as the others. The terms *anion* and *cation*—and the term *Ion*—are still less frequently employed."[22] Not until the theory of electrolytic dissociation began to occupy the attention of the chemical world did the Faraday-Whewell terminology really come into its own. All who deal with the passage of electricity through liquids or gases now find these terms indispensable.

Whewell's collaboration was again sought by Faraday in 1837, when terms were needed for his work on induction and discharge. *Inductric* and *inductreous* were taken by Faraday "for which with many others I am indebted to a friend." Again in 1850 Whewell was called to his aid, and *paramagnetic* came into being. His service on this occasion was rewarded with: "I, assisted by a kind friend, have thought that a word—not selected with particular care—might be provisionally useful."

Whewell once wrote:

> It is in a great measure by inventing *Technical Terms* that men not only best express the discoveries they have made, but also enable their followers to become so familiar with these discoveries, and to possess them so thoroughly, that they can readily use them in advancing to ulterior generalizations.—These terms soon become part of the current language of all who take an interest in speculation.—They carry with them, in their import, the results of deep and laborious trains of research. They convey the mental treasures of one period to the generations that follow, and laden with this, their precious freight, they sail safely across gulfs of time in which empires have suffered shipwreck and the languages of common life have sunk into oblivion.[23]

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[20] W. Whewell, "History," Vol. 3, 1847, p. 185.

[21] See the commendatory letter of Alexander von Humboldt in Bence Jones's "Faraday's Life and Letters," Vol. 2, p. 30, 1869.

[22] J. Tyndall, *op. cit.*, p. 55.

[23] "Philosophy," Vol. 1, 1847, p. 51.

THE PROBLEM OF THE CITY

THE FUNDAMENTAL PROBLEM OF HUMAN GEOGRAPHY

By KARL KEKONI
EKENÄS, FINLAND

INTRODUCTION

WHEN we approach the social sciences from the standpoint of human geography, we are astonished at the neglect of the city in current political doctrine. Though the city, directly or indirectly, provides the means for the material and intellectual progress of the mass of the people, yet it plays only a subordinate part in the political life of the nation. It is the country which is supposed to be the citizen's real home and field of action. It is to the state that he owes his faith and allegiance, not to his city. He may remove to the capital or any other city and begin operations which are destined to weaken and damage his former home without incurring any reproach. The structure of the modern state is based on the country and not on the city. In the education of the young, local life and endeavor are more or less neglected, and the process tends to foster nationalism, not local patriotism. In the organization of industry and trade little heed is paid to local interests and aspirations. Factories are closed and ports are abandoned without much concern for the consequence of these measures to the cities. We may indeed characterize the latest development of the modern state as an endeavor to detach the social life in all its aspects from the city and to substitute for local aims and intentions the aspirations and policies of the national state.

The modern neglect of the city stands in the sharpest possible contrast to the importance the city has had in the past for human development and culture. History and archeology teach us that since time immemorial the city has been the center of civilization by which the surrounding region has been raised from barbarism to culture. Science and art, philosophy and higher religion may indeed be regarded as the natural products of city life. The city existed before the state, which was created by it. In classical time the city was the acknowledged bearer of all political and social life within a certain area. According to the Greek theory of the state, as propounded by Plato and Aristoteles, the city and the state were one. Political constructions, resembling our modern national state, which comprises several city centers, were indeed known to the old philosophers but not accepted by them as a satisfactory basis of citizenship. It follows that to the modern statesman the Greek theory of the state is inadequate and of little practical value. This refers naturally to all the political ideas and theories of the state founded on the Greek conception: they all fail to solve or even to treat adequately the fundamental problem of construction, which is essentially a geographical problem.

THE CITY IN ANTIQUITY

Before we go further and show that the Greek conception of the city (*polis*) and the modern idea of the national state are incompatible with each other, it is necessary to give a short account of the position and function of the city in different periods of human development. First we should like, however, to emphasize the fact that even standard works of history do not pay sufficient attention to the city as an agent of progress and civilization. We might, indeed, put the question whether it would not be advisable to rewrite history and connect the account of events and persons with a number of leading cities and not with the states, which change and vanish, while the cities abide for hundreds and even thousands of years.

A few examples will show the justice of our remark. The usual treatment of Roman history tends to obscure the main fact that the Roman empire and the empire of the city of Rome are almost identical notions. All the aspirations and endeavors told by the Roman analysts, all the victories won and the battles lost, concern in the last resort the status and power of the city of Rome. From many points of view it would give a clearer and truer picture of the course of events to treat the whole story as the tale of a great city. The same refers to the history of the Byzantine empire, which is in reality nothing else than the history of Constantinople. Or again, to take another comprehensive view, when we study the history of the Near East during the Hellenistic period and wonder at the intensity of variety of life and endeavor then displayed by its peoples, and compare it with the backwardness and low level of culture now prevailing in that region, we must remember that in Hellenistic times Asia Minor and Syria were covered by a multitude of cities, each of which had a life of its own and functioned as a real center of commerce and culture. Most of these cities have been destroyed and can no more be reconstructed. Within the new Anatolian state there is only room for a growing capital, some struggling provincial towns and a few seaports, by which to carry on a limited foreign trade.

The glory of Greece and the grandeur of Rome really emanated from a number of wonderful cities, and it was to the destruction of these much more than to the dissolution of the political construction called the Roman empire that the downfall of classical culture was due. The decline of the old centers began with the Roman destruction of the Greek cities in Italy, Sicily and Greece and with the weakening of the city systems of Asia Minor, Syria and Africa. It was continued and finished by the barbarian invaders of the Roman empire, who themselves had no cities and did not understand the idea of citizenship.

The City in the Middle Ages

The Dark Ages following the dissolution of the Roman empire was thus mainly caused by the destruction of the old city system. There could not, indeed, be any progress of civilization or even preservation of the old culture with its science and art, as long as there was no society outside the church where men could find scope for their talents and capacities In a time when most peoples were wandering about and engaged in raiding and plundering only the warrior and the maker of weapons were held in esteem.

Europe had to wait 500 years before the morning dawned. It was not until the tenth century that the Italian towns began to show signs of revival, and a little later Europe entered on an era of city construction. Within an astonishingly short period the central and northern part of the continent were covered by a network of cities, which immediately began their civilizing activities. New trade routes were opened and connections established with countries and peoples far away in the north, which formerly were wholly outside of civilization. Trading stations were established, churches built and cities founded among the heathen peoples of the Baltic region, which were gradually converted to Christianity. Commerce and industry, which scarcely existed during the Dark Ages, revived and expanded as never before. In order to maintain and extend their trade and influence the cities formed confederacies, such as the mighty Hanseatic League, whose commercial activities comprised the whole of northern Europe from England to Russia and from Germany to Scandinavia.

The founding of the cities in the eleventh and twelfth centuries of the Christian era may thus be considered the fundamental event of European history. The different parts of the continent were welded together by the synthetic action of the cities. Natural barriers to trade and intercourse, such as the Alps of Switzerland and Tyrol and the forests of Germany and Scandinavia, were overcome by the endeavor of ever-widening commerce. Finally the ocean itself was conquered and connections established with strange lands and peoples beyond the sea. European civilization was thus enriched by new elements, the whole outlook was broadened and the field of action immensely extended. The era of world-wide commerce, of large-scale colonization and of high endeavor in the fields of science, art and religion had set in.

THE CITY IN THE PERIOD OF THE RENAISSANCE

The Renaissance thus really meant the reestablishment of the city as the center of civilization. While civilized life and culture during the early part of the Middle Ages and the period of the Crusades were confined to the monasteries and castles of the clergy and nobility, it was now extended to the homes of the burghers of the free city. This development and progress was not limited to the rediscovery and study of classical culture, but comprised the addition of much new thought and experience. Experimental science was born and soon became a powerful instrument of progress in the fields of theoretical and applied knowledge. Thinking and acting, philosophy and technical knowledge, which formerly had been separate fields of endeavor, were united to serve humanity. Materially, the free city became rich and powerful. Stately mansions and noble palaces testified to its wealth and prosperity and bore witness to its free and creative spirit.

At this point of our exposition it should perhaps be stressed that in two of the most important and splendid epochs of human development, the fifth century of classical times and the fifteenth of modern times, civilization and culture were directly related to the life of the free city. It should also be observed that the Renaissance was most clearly expressed in the municipalities of Italy, Germany and the Netherlands, while its influence was much weaker and limited to special branches of life in other countries, like France and England, where national states were in existence. By unification many of the old capitals, such as in France, Besançon, Nancy and Toulouse, had lost their position of political and cultural centers of definite areas and been brought under the authority of the national government, which was centered in Paris. The formation of the national state thus really implied the supremacy of the capital, which became the seat not only of the government and administration, but also of all the leading financial, commercial and cultural institutions of the country. This naturally led to a rapid growth of the capitals, especially Paris and London, while the provincial cities lagged behind and by degrees grew weaker and poorer. The result of this change is now most clearly seen in France, where the provincial cities are small and backward in comparison with the splendid centers of Germany and Italy, which until lately have preserved their position as capitals of natural areas.

THE CITY IN THE SEVENTEENTH AND EIGHTEENTH CENTURIES

In considering the position of the cities in the period immediately following the Renaissance we must remember that Europe during the seventeenth and eighteenth centuries was the scene of almost incessant strife. These devastating wars were highly detrimental to the cities. They did not only suffer from fire and sword but also from the loss of capital and men. In many cases they were isolated from their former uplands and areas of influence by new frontiers, which often cut across old trade routes and more and more hindered the internal commerce of Europe.

THE CITY IN THE NINETEENTH CENTURY

Thus the position of the cities in the century 1650–1750 steadily grew more unfavorable. Then, suddenly, the cities derived new energy and life from a mighty source, which for a long time secured their existence and growth. This source of power was implied in the great scientific and technical discoveries and inventions which were accomplished in the latter part of the eighteenth century and led to an immense expansion of industry and trade, accompanied by a rapid growth of population.

The great impetus to renewed endeavor in the fields of industry, commerce and finance thus given was chiefly felt in the cities. Most of the new mills and factories required for the mass-production of cottonware, woollen fabrics, iron tools and countless other objects of everyday use in a progressive society were located in villages and small towns, which, however, soon grew by immigration from the country. But the growth was not limited to the real factory towns. Other groups of cities, especially the ports, profited likewise from the expansion of commerce and shipping which followed the progress of industry. Many a little and dormant country town was stimulated to renewed life by being included in the network of railways which soon covered the country from end to end. Transportation and traffic both by land and sea gave employment and bread to a growing number of people, especially in the cities. Generally speaking, the machine altered the whole life and outlook of man, and created a new civilization, the bearer of which was the city.

THE ENGLISH FACTORY TOWN

It was in England that the industrialized society, thus created, assumed its most pregnant form. Thousands of factories were built, wholly altering the natural aspect of large parts of the country. These mills and factories were not, however, evenly distributed over the whole area but assembled in groups comprising the same and related industries. Lancashire thus became the district of cotton mills, West Riding of Yorkshire the home of the woollen industry, Staffordshire that of iron, steel and pottery, while Northumberland, Durham and South Wales became the principal regions of coal-mining. At the center of every district there grew up a large city, mostly consisting of mills, offices and shops and surrounded by an extensive area of slums, *i.e.*, overcrowded, dirty and unhygienic quarters, where a low standard of life prevailed, and poverty, vice and crime were at home.

When we consider the social weaknesses of the early English factory town, we must remember that it had no cultural traditions nor any means to raise its inhabitants to a higher level of citizenship. The Greek idea of the city was totally foreign to a community which was wholly preoccupied with the economic problems of wages, costs and profits. This want of foresight and narrow outlook on life naturally engendered that discontent and social unrest which finally took form in the political upheaval of the middle of the last century and which has continued to trouble and threaten the whole structure of society in England.

Much has in the meantime been done to improve the English industrial town and make it more attractive to its inmates. Overcrowded and unsanitary areas have been cleared and rebuilt with modern houses, providing more space and light than the old dwelling houses. Electricity has been introduced and put to the service of all at a low cost. Communication within the city area has been much improved by the introduction of mechanical vehicles of different types. Public libraries have been opened, schools of various kinds instituted, art galleries and in the larger cities even universities provided by the help of private munificence for the education of young and old. Yet there is much dissatisfaction and mistrust among thinking citizens. It is asserted in public utterances, in the press and in parliamentary inquiries that the provincial city is being neglected and its position weakened by the progress of central government, and the demand is put forth that the state should be decentralized, giving the city an opportunity to function as the cultural and political center of a definite region.

THE GERMAN CITY

As was the case in England, so industry greatly favored the growth of the cities in other European countries, especially Germany. Old centers of commerce and culture, such as Nürnberg, Augsburg, Frankfort and Cologne, which during the Middle Ages had been famous for their trade and industry, their craftsmanship and skilled workers but which had later declined, began to revive under the influence of expanding industry. A number of practically new towns, such as Mannheim, Essen, Elberfeld-Barmen, Hannover, Berlin, Chemnitz and Breslau rose in the valleys of the Rhein, Weser, Elbe, Oder and their tributaries. By the end of the nineteenth century German industry, centered in a number of rapidly growing cities, rivalled and in some branches surpassed English industrial activity. The old Hansa towns, especially Bremen and Hamburg, had grown into great ports, frequented by ships from every part of the globe.

It should be observed that only in exceptional cases did the German industrial city assume the grim aspect of the early English factory town. From the Middle Ages the German city had inherited a strong cultural tradition, which in a great measure tempered and counteracted many of the undesirable features of industrialization. And even after its incorporation in the federal state, the German city retained much of the old spirit of the free city. Moreover, the connection between science and industry, between craftsmanship and manual labor was closer in Germany than in England. The importance of technical education, both elementary and advanced, to the progress of industry was realized in Germany earlier than in England. It must be added that, generally speaking, the German city was better planned, better built and better governed than its English competitor.

Comparing the city systems of Germany and England we must remember that the former country, even after its unification, retained its local capitals. To such splendid cities as Dresden, München and Stuttgart, with their wealth of educational and social institutions, England can hardly show any counterpart except Edinburgh. And it is scarcely possible that such cities will ever rise in England as long as centralization continues to be the leading principle in the building and organizing of the state.

THE AMERICAN CITY

It is natural that the typical American city does not present the same picture of culture and refinement as do the old centers of Germany and Italy. Though well built and technically progressive and provided with many kinds of educational institutions, it seems to be too much dominated by the idea of business.

The American city does not as a rule function as the political and social center of a certain area, like the local capitals of Germany. It owes its wealth and prosperity almost wholly to its favorable position for industry and trade. The connection between municipal progress and industrial expansion seems so close in America that the problem of the city almost looks like a special problem of economics. But it is in reality far more than that. Whether a city will grow and prosper or languish and decay, depends on many circumstances which lie outside the economic field. Progress presupposes not only energy, ability and farsightedness in the leading members of the city, but also a sense of honor and duty and devotion to the common weal in every citizen.

While it seems hardly possible to exaggerate the part the American city has played in the development of the American nation and the wonderful country which is its home, yet it is evident that it has failed to act up to its opportunities. The causes of its partial failure may be many, but one is certainly that it has neglected to teach citizenship to its members. The significance of the idea has been obscured behind the conceptions and catchwords of party politics and economic strife. It is not generally realized that true progress and real culture mean inner growth, the unfolding of all the good and valuable capacities and qualities in every locality, community and individual, and not the imposition of an outer order and uniformity by the agency of a central government.

THE CITY AFTER THE WAR

Though industry little affected some groups of cities, it was undoubtedly the main factor in the great development the city-system of the world underwent during the nineteenth and the early decades of the twentieth century, including the period of the great war. The war itself highly favored the growth of a large number of cities by stimulating such industries as catered for the armies by providing ammunition, clothing and food. Many old factories were enlarged and new plants provided for the production of explosives and other articles of war, including ships. The industries worked under high pressure from the governments and employed a great number of laborers of both sexes, thus swelling the populations of the cities concerned in the trade.

From the capitalist's point of view the work was highly profitable as long as the war lasted. But at the close of hostilities the war industries were immediately faced with great difficulties. Large factories had to be altered at great cost or wholly scrapped. The products of many industries, which had been greatly expanded during the war, could not be consumed by a public which had been decimated and economically weakened. Large markets had been lost, presumably for ever. Many of the most important industries had to limit their output and rationalize their work, thus creating unemployment on a hitherto unknown scale. All this put a heavy and growing burden on the cities which already were pressed by high rates and large expenditures, consequent on the war.

CENTRALIZATION

The unsatisfactory position in which a large number of cities, especially in Germany and England, thus found themselves would not have been so serious and disquieting, had the causes of the trouble been of a temporary character. But on examination it was found that the roots of the difficulties lay very deep and were grounded in the new tendencies that more and more dominated the economic development all over the world. During the war several basic industries had been declared national concerns and put under the management of the government. Now it was urged by national economists and labor leaders that this state should continue even after the war. If we remember that the overwhelming number of factories and workshops in existence have been built by local endeavor and worked by local management, it is evident that this demand really meant a blow to the cities. And even if it has not been carried out in all its extent, it has had a destructive effect in stifling energy and enterprise in the cities.

It must be observed in this connection that the centralization of industry went on, apart from economic theories and political pressure, by way of amalgamation. In this process many of the small factories belonging to the same branch of industry were closed in favor of the larger units, which could be more highly rationalized and more easily financed. This led to a redistribution of industry which adversely affected many provincial towns, while greatly favoring the growth of the capital city. In England, for example, some of the most important industries "moved" southeast in the direction of London, carrying with them great capitals and large armies of workers. It has been calculated that in the period of the last general census 1921–1931 800,000 persons left the northern counties for London and its surrounding districts—one of the largest movements of people in modern times.

The changes in the structure and organization of industry, which entailed great social consequences, were not confined to England, but took place in most European countries, and were the principal cause of the enormous and disproportionate growth of such cities as Paris, Berlin, Moscow, Bucharest, Prague, Copenhagen, Stockholm and Helsingfors.

The method of amalgamation and centralization has not, however, been confined to industry, but applied to many other branches of economic activity. Thus in England, most local banks have been closed and replaced by branch offices of the large London corporations. The same tendency is visible in all European countries, most clearly perhaps in Finland, where practically the whole banking and insurance business is centered in a few large institutions with headquarters in Helsingfors.

Or, to take another important branch of commercial activity, from Liverpool and other shipping centers is heard a loud complaint that the northern ports are suffering by the diversion of traffic to London and its auxiliary ports. The Port of London Authority is spending enormous sums to provide new facilities for the ever-growing traffic on the Thames, while many of the Mersey-docks are empty. Similar tendencies in the shipping of Germany and Italy has led to government interference with a view to attain a more and just uniform distribution of traffic.

Centralization of trade and industry within the modern state has been much accelerated by commercial cooperation and monopolization, which is steadily gaining ground in most countries. Thus in Finland, which is perhaps in this respect the most advanced country in the world, the greatest part of the inland trade is now carried on by two or three great companies, which have their management, head offices and general stores in Helsingfors. The whole liquor traffic of the country is concentrated in the hands of a single company, which imports all the necessary wine and spirits exclusively through the port of Helsingfors.

Concerning the modern organization of inland trade we might add that all the most important products of Finnish industry, such as textiles, glassware, paper, tools and machinery, are distributed by central selling offices in Helsingfors.

When the modern organization of the foreign trade is examined, the same tendencies appear. It is not only in Russia that the export and import business is in the hands of a number of trusts, which have their headquarters in Moscow. Many other states are adopting the same system. Thus the export of all the principal products of Finland and Sweden is now managed by large corporations, which have their offices in Helsingfors and Stockholm. The organization of the foreign trade of Germany is developing along the same lines, while England and France are less advanced in this respect.

The main result of the far-reaching changes in the structure and organization of industry and trade, which we have briefly indicated, has been to increase the importance of the capital city and to strengthen its hold on the country at the expense of local centers.

It should, however, be observed that the rapid growth of the European capital during the last decade has not been caused exclusively by the concentration of industry and trade in its vicinity and within its borders. It depends largely, and in some cases principally, on the expansion of the machinery of central government and the growth of national institutions. In the modern capital whole quarters are filled with magnificent buildings, containing ministries and other government offices, law courts, national museums, central libraries and other institutions, which house the great and growing army of officials who more and more completely rule the state.

THE CENTRALIZED STATE

From what has been said it should be clear that the organization of the modern state is characterized by centralization and not by capitalism. Every political or social theory founded on the supposition that capitalism is the salient feature of the modern European state is wholly wrong and misleading.

The fault with the state is in its structure and not in the economic system. The organization is proceeding according to a principle which, while favoring the growth of the capital city, weakens the provinces and creates distressed areas and derelict cities.

In fact, if we undertake a survey of Europe from this point of view, we shall find a great and growing number of towns and cities, scattered over the whole continent from Spain to Finland, which have ceased to grow or are in a state of decay. The apparent cause of failure is in most cases dislocation of industry and trade or the gradual detaching of the city from its upland, without which it can not prosper. But these changes are, as we have seen, only the natural consequences of the application of the idea of centralization to the organization of the state.

There is, however, another tendency in the development of the modern state which is contrary to the progress of the city. It is the new nationalism which is fast growing in most European countries. In order to understand its pernicious influence in this respect, we have only to consider that the city must acquire a more or less cosmopolitan character if it is to function as a real center of civilization and progress. It must endeavor to form better connections not only with places inside the national state but also outside the latter. It must seek to enter into closer and more intimate relations with foreign countries and to understand and cooperate with foreign peoples. All this, however, is contrary to the nature of the modern national state, which endeavors to be self-supporting and self-sufficient. In reality, the idea of the state and the idea of the city are contrary notions. The former is morally founded on the ideas of authority and obedience, the latter on those of initiative, energy and cooperation.

CAN WE BE SOCIALLY INTELLIGENT?

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MR. OWEN D. YOUNG is reported to have said that society to-day is in the position of Columbus who, when he started out did not know where he was going, when he got there did not know where he was, and when he returned did not know where he had been. The chaos and confusion that characterize our social household in industry, economics, morality, religion and any other phase of our group life, plus the shouting and tumult of self-designated Messiahs, each with his alleged sure-fire gospel of social redemption, certainly indicate that we are just muddling along in our effort to discover the promised land of social welfare, and that if the journey does not end in disaster it will be by chance and not by choice. Are we then destined to keep on drifting and floundering on the stormy sea of social life and take our chances of either being wrecked or land safely, guided only by the winds and waves of circumstances, or can we set our sails and steer our course towards a definite goal with some assurance that we shall reach it in comparative safety? In other words, can we manage and control our ship of life intelligently, with forethought and foresight, by having captains at the helm whom we can trust, or must we resign ourselves to the belief current in some quarters that social progress by intelligent guidance and direction is a delusion and social drift by muddling along as best we can the only stark reality?

A promising approach to this problem is to examine what constitutes an intelligent approach to a situation and then see whether instances can be cited from past history of any human interests to which such an approach had been made and what fruits it yielded.

What is an intelligent situation? This question is not as puzzling as it may appear to be on the surface. A situation is intelligent when it is under control, when the human mind manages the situation instead of the situation managing the human mind. And control depends upon the operation of two factors in any situation. First is a knowledge of the situation derived from the nature of the situation itself, that is, what the situation in itself actually is, rather than what we would like it to be or what we believe it should be or ought to be. Knowledge that yields control is present only when we act in the light of what we *can* believe on grounds of reliable evidences, and not what we *like* to believe because it is in conformity with our preconceived notions, purposes or prejudices. To accept knowledge because we like to believe it is to harbor fancies and delusions, and therefore to be enslaved to the situation, for a situation will yield to control only when it is respected and not when it is imposed upon. The person who begins to accept the fancies of a day-dream for the facts of reality is taking the first steps to a lunatic asylum. And this is as true socially as it is individually, for society can be, and at times actually is, as insane as an individual. So intelligence, in one of its two aspects, consists of a conscientious effort to get at the facts in the case. But a knowledge of the facts will not in itself result in control, for such knowledge may be used only to carry out a destructive purpose, and consequently, the more knowledge there is the more mischief-producing it may be in its application. We have a capital example of this fact in the socially destructive results that have followed in the wake of the progress of research in the physical sciences. The fault here does not lie in the knowledge, but in its application. The more knowledge that the schemer and plotter possesses in the field of his activities, the more destructive he becomes. Consequently, a second factor in intelligence is an examination of the ends or purposes to be achieved by the knowledge of a situation. This is the factor of self-examination, or knowledge of oneself: the distinction between the worthy and the unworthy, the fit and unfit, the human and the inhuman, and constitutes the ethical or moral phase of intelligence, as the other is the material phase. And the two are inseparable, for where there is no knowledge of the material situation the human being is a victim of the situation by being enslaved to it, and where there is no knowledge of the human situation, or motive, and action in keeping with this knowledge, the human being is victimized by himself by being enslaved to himself. There can be no real control of a situation, and therefore no intelligence, apart from self-control.

Man, then, can be intelligent, for he has the power of knowing both himself and his world, and thus control situations for his welfare. And we have ample historical evidence that where man has used his powers of intelligence he has prospered beyond his expectations or even his fondest dream. The physical sciences have transformed the physical world within the short period of two or three centuries. Sky, earth and water are being increasingly subjected to his will and for his use. And what the biological sciences have accomplished for the physical ills of man is common knowledge. In these we have not been drifting and muddling, but pressing onwards with a clear goal before us and a clear road ahead of us. And all this because of the operation of intelligence. The scientist, whether he deals with the inorganic or organic, obeys both laws of intelligence; he controls himself by not imposing what he would like to believe upon the situation, but accepts what he can believe because it is what the situation tells him about itself. Because he controls himself he is rewarded with the control of the situations he studies, and thus becomes a blessing to mankind.

Obviously, then, our failure to control our social world, as is indicated by the persistent recurrence of some problems and the increasing virulence of others, is an indication of the lack of intelligence in our approach to them. In what way, then, do we fail, and why?

We fail to be intelligent in social affairs in two ways: one by misusing the fruits of the physical sciences and thereby bringing numerous social evils down upon ourselves, and second, by our failure to apply to social ills even as much scientific knowledge about social life as we possess.

A recent editorial in the *New York Times,* in commenting on an address of Sir F. Gowland Hopkins before a meeting of the Royal Society, in which the speaker touched on the question of the scientist's relation to society, makes the charge that scientific research "has something unethical about it because of its disregard of human values," in that "to invent the steam engine, to create vast pools of electric energy and let a nation use them without any regard for the social and economic consequences is a violation of all scientific principles." Now this is an old story. We have heard the tale repeatedly that whereas our material progress as a result of scientific research has been unparalleled, spiritually we have been at a standstill or perhaps even retrogressing. This may be an overstatement of the case. But no one can deny that ethically we have not kept pace with our material advancement and that in the wake of scientific advancement there have followed numerous new social evils, while many old evils have grown in gravity. Wars are not only still with us but science has made them more deadly and devastating.

But should we remain satisfied with stating the case and dismiss it by laying the responsibility at the feet of science, or propose, as some have done, that we take a scientific holiday during which we can catch up on our ethical delinquencies? Is that an intelligent approach to a problem, or is it not rather an evasion of the issue? Certainly, in themselves the fruits of science can not possibly be evil, for science means knowledge, and knowledge is the tool for adequate control. Hence, the evils connected with science can not be due directly to the results of scientific research, but must arise from the misuse of these results. And they are misused not by those who have created them, but by those who exploit these results for private gain. It is then the unscientific, the unintelligent, use of the fruits of the sciences, that brings upon us the evils of which we complain, and not the fruits in themselves. If the leaders in political, industrial, financial or any other social affairs were actuated by the same spirit that controls the leaders in scientific matters, namely, the search for truth, and not merely by schemes for power and profit, the fruits of the tree of scientific knowledge would nourish the social body instead of poisoning it. If a scientist discovers a labor-saving device or a means for increasing production he does not thereby incur the obligation to civilize or humanize the industrialist and manufacturer who might use his discovery in a socially destructive manner. We need intelligence or the spirit of science among those who have the means and the power to misuse the fruits of the labors of the scientist for the satisfaction of greed and avarice. The scientist presents human beings with the gifts for more abundant life, and if these gifts are misused and increase the burdens of life, the fault lies in our stupidity and not in the scientist's wisdom.

Furthermore, not only do the recognized leaders in social affairs misuse the fruits of science, but actively oppose the scientific regulation of these affairs for the common good, by organized propaganda in the interest of the *status quo.* And their propaganda invariably succeeds, at least temporarily, because they clothe their selfish purposes in the garb of altrusim, by proclaiming for their sole motive the promotion of the public good and by branding the advocates of change in the direction of regulation and control as the enemies of the state. We have had recently a capital illustration of the machinations of the enemies of progress by intelligence in the "ganging-up" against the New Deal. Now there is no intention here of defending the policies of the present administration. It is very possible that these policies are erroneous, and even their most enthusiastic supporters do not claim that they are flawless. But one thing is certain, and that is, that most foes of these policies do not oppose them on the grounds that they are fallacious. If their opposition arose from that source they would examine the policies in terms of their own merits, which would constitute a scientific or intelligent approach. But instead of that they appeal to prejudice by proclaiming that the New Deal is contrary to American principles of democracy or constitutes a threat to American standards of living or is a menace to American freedom and personal initiative—all meaningless generalities, empty phrases, but for this very reason the more effective in blinding the public to the real issues and problems at stake. A principle or a tradition can have no soundness in it if the results to which it gives rise are undesirable. Even the Constitution of the United States is not too sacred a document to stand in the way of public and national welfare. What is needed, then, is a critical examination of principles, traditions and even the Constitution, and not oratorical outbursts in their defense, for whatever stands in need of constant defending and can not stand honest examination condemns itself by that very fact as being false. And those who resort to denunciation and obstruct examination are not so much concerned with preserving the principles they proclaim as with saving their own necks. Their shouting for principles is but a smoke-screen behind which they hide their real motives. We have many illustrations in history of such tactics of the enemies of social progress. The politicians of Athens did not examine the moral ideas of Socrates, but raised against him the hue and cry that he was an enemy of the state, that he preached strange gods, that he was a menace to youth in making the worse appear the better cause. And they succeeded in having him put to death. The priests of Jerusalem raised an outcry of blasphemy and atheism against the spiritually-minded Jesus not so much because they had any genuine concern for spirituality but because his teachings constituted a menace to their power. And they succeeded in having him put on the cross. The Holy Inquisition expressed grave concern for the protection of the infallible truth of Holy Writ as the grounds for hounding and persecuting the scientists of the period, but its concern for Holy Writ meant no more than a determination to assure the control of the human mind by the churchmen for their own purposes. And they succeeded in obstructing the progress of science for centuries. The price for the evils that invariably follow in the wake of such tactics is never paid by the tacticians but by the human family, the innocent and helpless victims of the greed of the few and the mighty.

But why is the human family so easily victimized by those who set out to prey upon it and thereby fails to manage its affairs intelligently? Why does their propaganda succeed in deceiving the human family? The answer is because the propagandist, whether politician, priest, pedagogue or professional reformer, is shrewd in his tactics. His shrewdness is three-fold.

First of all, as has already been hinted, he masks his greed for power and pelf in a cloak of altruism. He never speaks in his own name, but in the name of God or man. He never expresses opinions, but utters oracular truths to be accepted without question. This gives him a weapon against those who doubt his words, by branding them as atheists, unbelievers, enemies of God and man. The politician or priest will not discuss with his opponents. He will smite them, brand them, attack them, denounce them and persecute them. To doubt him is to cast aspersions on divine truth. His voice is the voice of God and the voice of the human cry for salvation. The human family is deceived by him because of his loud voice and louder claims for self-sacrifice and self-denial. The searcher for truth has no inclination to shout from the house-tops, to announce himself a Messiah, to proclaim finalities, for he is too busy searching and is ever in doubt of his findings. Truth is not an accomplishment, but an accomplishing, not a finding but a seeking, not a loud shout, but a quiet, patient and long search. And man is impatient, and therefore easily deceived by fancies presented as finalities. Initially a fancy is more appealing than a fact, since it presents an easy way to a desired end. Its delusive nature makes itself known only in its devastating results, when another fancy is offered as a way out of the dilemma. So the human family has been pursuing will-of-the-wisps, stumbling along, and saved from falling and breaking its neck by no one knows what. Life will persist even against what seem to be overwhelming odds, which is but an indication of what it might attain were it to direct itself by fully conscious means and ends. And it would do so were it not for the plots and schemes of those whose purpose is well served by keeping it in the dark.

The exploiter of mankind succeeds, in the second place, because he offers easy and quick ways to salvation. All we need do is follow his panaceas, and we shall reap a rich harvest. He boasts of being practical, and dubs those who advocate caution as empty dreamers and wide-eyed idealists. If we follow him in any direction in which he leads we shall reach a desirable destination by a leisurely stroll through pleasant country. The way of the dreamer and idealist is slow and laborious; and no guarantee given. We have to blaze the trail, study signs, and we may even get lost and have to find our way back and begin all over again. "Follow me," cries the political Messiah, "and by a mere vote you will enjoy a secure and happy old age." "Follow me," proclaims another, "and by a mere political pressure, quite painless, you will enjoy the fruits of the world now, and not have to wait for old age." "Follow me," shouts the spiritual Messiah, "accept ready-made beliefs, and engage in certain easy, even pleasant practices, make a small contribution for my support and comfort, and you shall have attained peace and prosperity here and bliss in the hereafter." "Follow me," pants the moral Messiah, "conform to my set rules for conduct, at least outwardly, and you shall have public virtue, approval and good business, without regard as to what is in your heart or what you do in private." And if the panacea is not accepted willingly by human beings it is to be forced upon them by any means possible or available. In the meantime each Messiah is busy not only in proclaiming his own panacea and urging its adoption, but in denouncing other Messiahs in his field as false prophets. So the captains are sailing their ships on the troubled sea of society, each steering in a different direction with one hand and with the other shaking a fist at other captains. And the passengers on each ship are certain that they, and only they, are headed for the haven of refuge, and all others are on the way to perdition. But none know definitely just where they are going, why they are going at all, or just how they are to get there.

A third factor that accounts for the success of the predatory individual and group in deceiving the human family, consists of a set of well-established alibis that absolve them from responsibility for the evils created by their operations. These alibis parade in the name of religion and science. We have evils with us, the theologian tells us, not because of the failure of his dogmas to bring peace on earth by creating good-will among men, but because of man's natural and utter depravity, which inclines him to prefer evil to good. The world, he proclaims, is a battle ground between the forces of good and the forces of evil, between God and the devil. Man has the power to choose between them, but in spite of his being urged by the hosts of the Lord to walk the pathway of righteousness and receive a reward, he harkens unto the disciples of the devil and walks in iniquity, just because that is his nature. So those who prey upon human beings and human nature by libelling God and man keep their pie and also eat it: they profit by their depredations and remain innocent of the evils they create.

Or we have evil in the world, say those who find theological excuses outmoded, because of our biological and evolutionary inheritance. We inherit traits from our ancestors that lead us or even drive us directly and inevitably into evil, so we can lay the responsibility at the feet of the dead past. This is a most convenient and easy way out, and all scientific evidences that our social problems are psychological and not biological in origin are of small avail, since a justification for the existence of an evil is far more welcome than an examination of its causes.

Then, if biological heredity fails, evolutionary heredity comes to the rescue. Our evils, we are told, come to us from our animal inheritance, or our instincts. We fight because of our pugnacity instinct. We have industrial strife because of the instinct of acquisitiveness. We meddle and pry into each other's affairs because driven to it by our curiosity instinct. We belittle each other, gossip and blacken character, because of the instinct of envy or jealousy. Scientific evidence to the contrary notwithstanding, namely, that these modes of behavior are habits, and therefore subject to modification and even eradication, we nevertheless cling to them because they justify our doing as we have been doing and desire to continue doing.

So we remain unintelligent in managing our social affairs and go on suffering. But must we continue to do so? The answer is, obviously, that we can help ourselves provided we are willing to face our problems intelligently, by examining their causes and treating them in the light of the causes. And we can do so, since we possess the power of being intelligent and therefore can become actually intelligent. Our ills are of our own making, and therefore we can also unmake them. To do so we must make at least three moves:

1. We must rid ourselves by a process of education of some traditional modes of thought about human beings and human nature which have served the purpose of evading difficulties rather than facing them and dealing with them. Those modes of thought consisted of ideas we liked to believe, and we need ideas we can believe. We have a tool to-day for obtaining such ideas in scientific method, so there is no justification for our dealing with human problems by talk, no matter how attractive or consoling it may sound. Words are valuable only when they are used to report knowledge, and not as substitutes for knowledge. Dogmas, maxims, proverbs, injunctions, pleadings, preachings and warnings might have served some purpose when there was nothing better available. To-day we don't need to impose on man arbitrarily concocted laws and principles, for we possess laws and principles derived from man, which he does not have to be compelled to obey because he already does obey them in that they are the laws and principles of his being. And no law for the guidance of man can have any validity in it unless it is a law that is true to his nature because derived from his nature. Whenever human beings have to be driven to conform to a law it is an indication that the law is false. There is no value in legislation or any other form of compulsion, for all legislation is a palliative, a sedative, not a cure, since it does not touch the cause of the evil, but only suppresses its symptoms, which is dangerous. Human beings can find out from themselves and by themselves as to what is good for themselves, and as they find this out they will also do it without any urging, driving or tempting.

(2) We must drive the money changers from the temple of science and learn to use its fruits for the good of all. The money changers have been and still are with us in other parts of the temple of the human spirit. Good business is still being carried on in the name of religion or morality. But we have been learning to distrust these money changers, and with the waning of their influence human welfare has increased. We have dismissed the theological mind from meddling and dictating in science, and science has rewarded us beyond our fondest dreams. As we learn to prevent the avaricious mind from using the fruits of science for its own purposes we shall find that these fruits will nourish the entire social body and increase its health materially and spiritually. The earth and the fullness thereof which science is increasingly revealing to us and making avail-

able for us need not be used merely to increase the fullness of those already well filled. They can be used to give fullness to all that are willing to work for it. Call this outlook by any name you please to make it appear threatening, but its one real name is humanism. A society in which some human beings have to starve, while others are gorged to suffocation and still keep on gorging, is not a human society nor even beastly, for a beast is through when it has had enough and willing for others to come in and feast. No beast can be as beastly as a human being when he begins to act as a beast The sciences have provided a feast for all, and therefore let all partake of it in accordance with their normal human needs, in a normally humane manner He who can not be human has no place among human beings, for he will dehumanize all if permitted to carry on The person whose "intellect is that of a chameleon who knows when to change his color, of a crab who knows when to dive into the sand, or of a wolf who knows how to stalk his prey" has no place in an intelligently ordered society, and if he succeeds in hiding his chameleon-, crab-, wolf-like activities he will bring about a chameleon-, crab- and wolf-like society.

Finally, we must apply to social ills the knowledge the social and biological sciences have given us, directly or indirectly, about human beings and human nature. This knowledge shows us in unmistakable terms the mistakes we have been making and also how to rectify them. Genetics, anthropology, the various branches of psychology sociology: all throw the bright light of understanding upon many of our most troublesome and persistent ailments like crime, delinquency, insanity, instability of character, thwarted or distorted mental development—all of which are at the basis of our disordered society. Bring up a generation of sound individuals in body, mind and spirit and you have a healthy, sound, harmoniously functioning social group. An individual is in conflict with others because he is in conflict with himself. Remove his inner conflicts, or better, do not permit their occurrence, and you have removed or prevented the causes of outer conflict. Social diseases are like physical diseases. They do not merely happen, they are caused. And the biological and social sciences point out the causes. If we fail to use this knowledge we have neither nature nor some mysterious divine or devilish forces to blame, but only our own inertia.

In sum, we can be socially intelligent if we deliberately and conscientiously set out to be so All we need do is realize the causes of our unintelligence and proceed to deal with the evils they have brought down upon us by placing our confidence in the social leadership of those persons who have proven themselves worthy of confidence by the constructive fruits of their quiet and relentless labors, namely, the great dreamers and idealists of the ages Everything we possess to-day of positive value to man has come to us from them, in spite of our disregard of them and in spite of the opposition to them of those to whom truth is a menace. We can establish them in positions of leadership and trust implicitly in their guiding hand. We have had enough experience, bitter experience, throughout centuries of suffering and anguish to realize the soundness of Plato's proclamation some 2,300 years ago that, "Until philosophers are kings, or the kings and princes of this world have the spirit and power of philosophy, and political greatness and wisdom meet in one, and these commoner natures who pursue either to the exclusion of the other are compelled to stand aside, cities will never have rest from their evils—no, nor the human race, as I believe—and then only will this our State have a possibility of life and behold the light of day."

GROUP THEORY FOR THE MILLION

By Professor G. A. MILLER
DEPARTMENT OF MATHEMATICS, UNIVERSITY OF ILLINOIS

GROUP theory is not explicitly included in the recent unique and popular book entitled "Mathematics for the Million" by Lancelot Hogben, F.R.S. This may be due to the fact that this interesting book emphasizes the body of mathematics more than its soul. It unfortunately assumes a somewhat contemptuous intolerance for all mathematical work which is not undertaken directly for the improvement of social conditions, and hence it overlooks one of the mainsprings of mathematical progress during all the ages; *viz.*, the search for new truths and the delight in seeing things from a new and more general point of view. Mathematics for the million naturally devotes little space to the most elementary parts of this subject, which are of interest to a much larger number of people. It also properly excludes the advanced developments of this subject, since these are of interest to only a small number.

There is, however, a considerable body of group theory knowledge which may reasonably be regarded as belonging to the mathematics for the million at the present time. This includes the knowledge of the cyclic groups as well as of a number of non-cyclic ones. Among the latter the one which involves four operators is the simplest, and its usefulness is attested by the fact that it appears under five entries in the recent second edition of "Webster's New International Dictionary" (1934), as follows: "anharmonic group," "axial group," "cross-ratio group," "four-group," "quadratic group." As an abstract group it is characterized by the fact that in addition to the identity it is composed of three operators such that the product of every two is the remaining one and the repetition of each is equivalent to the identity. It is illustrated by the movements of space which transform a general plane rectangle into itself. The three movements of period two are the rotations around the lines of symmetry of this rectangle through 180°, and the rotation through the same angle around the perpendicular to the rectangle at its center.

The circle embodies every cyclic group, but it embodies much more. The properties of the circle which seem to have first attracted attention, such as the determination of its approximate area and the approximate ratio between its length and the length of its diameter, have nothing in common with group theory. On the other hand, its generation by the repeated rotation through the same angle measured by a number and the different possible selections of the operators which may be used to generate these rotations are group theoretic questions which received attention only in comparatively recent times. This seems to be due to the fact that in modern times there has been a growing tendency to substitute more and more the study of the dynamics of the phenomena in place of their static properties. The idea of evolution dominates more and more the scientific thought, and this idea is the source of the modern emphasis on group theory in mathematics.

It would be difficult to find a more forceful illustration of the fundamental fact in the history of mathematics that the developments of this subject are largely affected by the spirit of the age than is furnished by the emphasis on group theory during recent times. In particular, the cyclic group might have been emphasized in the study of the circle even in early times, but it was not until the nineteenth century that this group received much attention in connection with this study. The growing emphasis on this group was also largely due to the fact that during the nineteenth century it became more and more clear that a large number of mathematical problems are inherently reducible to non-cyclic groups, and hence the study of the cyclic group was seen to be the natural entrance to various broad realms of mathematical ideas. Family connections in mathematics have been no less influential in bringing certain subjects temporarily into the limelight than similar connections in the social world.

The definition of the concept of group is so very simple that one might at first suppose that little could be accomplished by the use of this concept. In addition to the fact that when three or more elements of a given set are combined, two at a time, the associative law is obeyed, it is only required that when any two of the symbols in the equation $xy=z$ are replaced by the same or by two distinct elements of the set then the third of these symbols can be replaced by one and only one of the elements of the set. Contrary to a widely quoted statement, the natural numbers do not constitute a group when they are combined by multiplication, as may be seen by replacing z in the given equation by a prime number and replacing one of the other symbols of this equation by a different positive integer. The common integers, including zero, obviously constitute a group according to the given definition when they are combined by addition, zero being the identity element. This constitutes one of the most useful groups in the entire field of group theory.

Notwithstanding the fact that the definition of the concept of group is very simple and can be stated in a few words various writers have failed to observe even these mild restrictions in the use of the term group, as may be seen from the reference to the natural numbers in the preceding paragraph. This could be more easily tolerated if it could be proved that a widely useful abstract theory could be based upon the definitions employed by them. Such a proof has never been given so that there is to-day essentially only one abstract group theory, namely, the one which is in accord with the definition quoted in the preceding paragraph This is especially true as regards groups of a finite number of elements, which have been primarily in mind in the present article. It is well known that each of these groups presents itself once and only once among the regular permutation groups, and hence these groups appear in a concrete form as well as in an abstract form.

Every child uses groups long before it is confronted with the name of this concept as a mathematical term. When the face of the clock bears a certain number of numbers, such as 12 or 24, to represent the hours, it is clear that when a certain number of hours is added the result is equal to one of these hours with respect to a given modulus. That is, the numbers on the face of a clock constitute a cyclic group with respect to the modulus which is equal to the largest of these numbers, and this largest number is the identity of this group. Similar remarks clearly apply to the number of the days of the week or year. Why, then, did people not always take an interest in these groups as mathematical concepts and consider the order of their operators, the number of their generators, the number of their subgroups, etc.? These group theoretic questions when applied to the face of the clock appear at first to be of minor importance. They become very significant only when they are viewed from a higher point of view as related to a subject of great usefulness.

The man who sees the cyclic group on the face of the clock obviously has a richer life than the one who sees only the numbers thereon. Similarly, the cyclic group becomes much more impressive when viewed as a corner-stone of the large edifice of group theory than when it is considered by itself. The movements of space which transform various regular geometric figures into themselves exhibit other important parts of this edifice. Notwithstanding the fact that these figures have been studied for thousands of years, their groups were not explicitly noted until recent times, and this is another forceful illustration of the fact that the developments in mathematics have been largely influenced by the scientific spirit of the times when these developments were made. The movements which transform the regular plane polygon of n sides into itself constitute the dihedral group of order $2n$, composed of the cyclic subgroup of order n formed by the movements which do not interchange the sides of the plane in which the polygon is located and the n rotations through 180° around the lines of symmetry of this polygon.

An interesting property of the group of the regular plane polygon of n sides is that it is generated by two of its rotations through 180° around two distinct lines of symmetry irrespective of the value of n. From the standpoint of abstract group theory it is important to note that whenever two operators of order 2 have a product of order n then these operators generate the group of movements of the plane regular polygon of n sides. This is an instance of the remarkable simple abstract definitions of the group of movements of the regular figures in elementary geometry. The facts that two group operators of the order 2 invariably generate the dihedral group whose order is twice the order of the product of these operators and that there is one and only one such group of every even order are primary facts in the theory of groups and exhibit in part the fertility of the simple definition of an abstract group. While there is one and only one cyclic group of every order there is one and only one dihedral group of every even order.

The groups of the regular polyhedrons of elementary geometry are also remarkable for their simple abstract definitions, which were first pointed out by a noted Irishman, W. R. Hamilton, in 1856, after these solids had been studied for more than two thousand years. Abstractly, these groups are separately generated by two group operators of orders 2 and 3, respectively, whose product has one of the following three orders: 3, 4, 5. When this order is 3 there results the group of the 12 possible movements of the regular tetrahedron; when it is 4 there results the group of the 24 possible movements of the cube as well as of the regular octahedron, and when it is 5 there results the group of the 60 possible movements of the regular icosahedron as well as of the regular duodecahedron. The remarkable simplicity of the definitions of these groups from an abstract point of view suggests an explanation of the attractiveness of these solids since the times of the ancient Greeks and adds greatly to this attractiveness from the more advanced point of view.

The basis of symmetry is the group of movements which transforms the symmetrical figure into itself, and symmetry has always played a fundamental rôle in intellectual work. This is illustrated by the facts that the square was most commonly selected even by the ancients as the unit of surface measure, while the cube has been most commonly chosen as the unit of solid measure. On the other hand, the groups of movements of the square and the cube failed to receive explicit notice until recent times. These groups are, however, not mainly of interest because they throw light on the selection of these units of measure, but because they exhibit connections relating to various other subjects. Their connection with the common units of measure seems, however, to justify the view that they are for the million and should tend to deeper intellectual insight on their part, at least with the advance of enlightenment

It seems natural to inquire how the mathematical world first gained an entrance into the theory of groups as contrasted with the use of special groups, which was very early as noted above. This unconscious entrance is apt to throw light on how the modern student can most easily secure a knowledge of this growing and widely used theory. The proof of the fact that when a group appears within a group the order of the latter is divisible by the order of the former seems to have furnished the first solid foundation for the theory of our subject. This fact is known as the theorem of Lagrange (1736–1813), although Lagrange could obviously not have proved it in its general form, since he died before the theory of abstract groups was founded. It is an illustration of many cases in the history of mathematics where a wise start is glorified by the successful labors of succeeding generations. In fact, the entire theory of abstract groups may be regarded as a glorification of the earlier developments in the theory of permutation groups.

The theorem of Lagrange suffices to prove that there is only one group of a given prime order, since every operator of such a group, besides the identity, generates the entire group because the group contains no subgroup besides the identity. A proof of the theorem of Lagrange results very easily from the rectangular arrangement of the operators of a group in which the first row is composed of the operators of the given subgroup. A second important entrance into the theory of groups was effected by the proof of the fact that when the order of a group is divisible by a given prime number then the group contains a subgroup whose order is equal to this number. The famous French mathematician, E. Galois (1811–1832), who is the only noted mathematician who died before he was twenty-one years old, stated this theorem without recording a proof thereof. After it was proved by A. L. Cauchy (1789–1857), a solid foundation for progress was laid and many writers built thereon and are still actively engaged in adding to the superstructure.

—*Photograph taken at the Toronto meeting of the British Association for the Advancement of Science, August, 1924*

LORD RUTHERFORD OF NELSON

THE PROGRESS OF SCIENCE

RUTHERFORD

THE name of Rutherford will be forever identified with radioactivity and the nucleus of the atom. In a scientific generation whose great problem was the structure of matter, Rutherford directed the new-found powers of nature to uncover her innermost secrets. Rutherford approached his scientific problems with vigorous directness, steering straight to the heart of the matter, using whatever tools were most suitable, pressed on by a burning urge to find the truth. His genius was to plow through a tangle of data and guesses and bring into obvious view the underlying facts. Himself a great leader in science, he has passed the blazing torch to hundreds of younger men.

Lord Rutherford was born in 1871 as Ernest Rutherford, in the little town of Nelson, in the South Island of New Zealand. He made a brilliant record at Canterbury College and New Zealand University, and went to Trinity College, Cambridge, in 1894. His studies during this first Cambridge period included work on electric waves, in which he developed a detector of increased sensitiveness and important observations on the ionization of gases, in collaboration with J. J. Thomson. From Cambridge, Rutherford went to McGill University as Macdonald professor of physics, where between 1898 and 1907 he did his most important work on radioactivity. The next period of twelve years was that in which he developed the nuclear concept of the atom. As Langworthy professor at Manchester, he not only performed his own brilliant experiments on the scattering of alpha rays, but also stimulated the equally fundamental work of Bohr and Moseley. After the war, he accepted an urgent request to go to Cambridge as Cavendish professor, where he was destined to make the Cavendish laboratory, already notable for the great researches of Maxwell, Rayleigh and Thomson, preeminent in the world-wide attack on the structure of the nucleus.

If the record of his discoveries is to be paralleled in the annals of physics, it will be only by a Newton or a Faraday Consider some of them: Working with J. J. Thomson on the effects of x-rays, Rutherford gave the first convincing proof that electric current passes through gases because of the presence of charged "ions." This was the foundation stone of our knowledge of the mechanism of conduction of electricity through gases. His brilliant researches established the existence and the nature of radioactive transformations. He was the leader in the analysis of the rays from radioactive substances into the alpha, beta and gamma rays, and the identification of these rays as doubly charged helium atoms, electrons and electromagnetic radiation, respectively. An incident in this work was his measurement of the electronic unit of charge with a precision many times greater than that of earlier determinations and adequate for the contemporary needs of the electron theory. Using alpha rays as his tool, he established the theory that the atom has a concentrated, electrically charged nucleus which possesses nearly all the atom's mass. He tested the laws of electric force for sub-atomic distances, and measured the electric charges of his atomic nuclei. That these nuclei were not elemental things, he proved by disintegrating them with alpha rays, discovering in the process that the proton, the nucleus of the hydrogen atom, is a component of the heavier atomic nuclei. Under his immediate encouragement were performed Moseley's remarkable x-ray experiments that showed the

—*Photograph taken at the Toronto meeting of the British Association for the Advancement of Science, August, 1924, by Arthur H. Compton*

LORD RUTHERFORD AND SIR WILLIAM BRAGG

meaning of atomic number in terms of nuclear charge, Chadwick's discovery of the neutron which forms a part of the nucleus, Cockcroft's artificial disintegration of nuclei and Niels Bohr's development of his theory of the atom. A large part of the development of modern physics thus occurred within his brain and was established by tests made with his own hands.

Strength and contagious enthusiasm were outstanding characteristics of Rutherford. His interest was an inspiration to those who worked with him. While not infallible in his inferences and conclusions, his clear physical intuition was at times almost uncanny in its accuracy. His powerful physique suggested a lethargy that was belied by his nimble wit, which on more than one occasion was effective in exposing the pretensions of too careless theorists.

Rutherford's great powers were not used in the laboratory alone. In his later years, he took an active part in applying science to the public welfare. As president of the British Association for the Advancement of Science and for a number of years also of the Royal Society, he was an effective public exponent of science.

Universities, societies and academies at home and abroad were pleased to have Rutherford accept their honors. He was knighted in 1914 and received the Order of Merit in 1925. It was with no little hesitancy that in 1931 he allowed himself to be created first Lord Rutherford of Nelson. His characteristic democracy, however, enabled him to keep close to his scientific colleagues, and he felt that he should not make it too difficult for his nation to recognize the importance of the contribution that was being made by science.

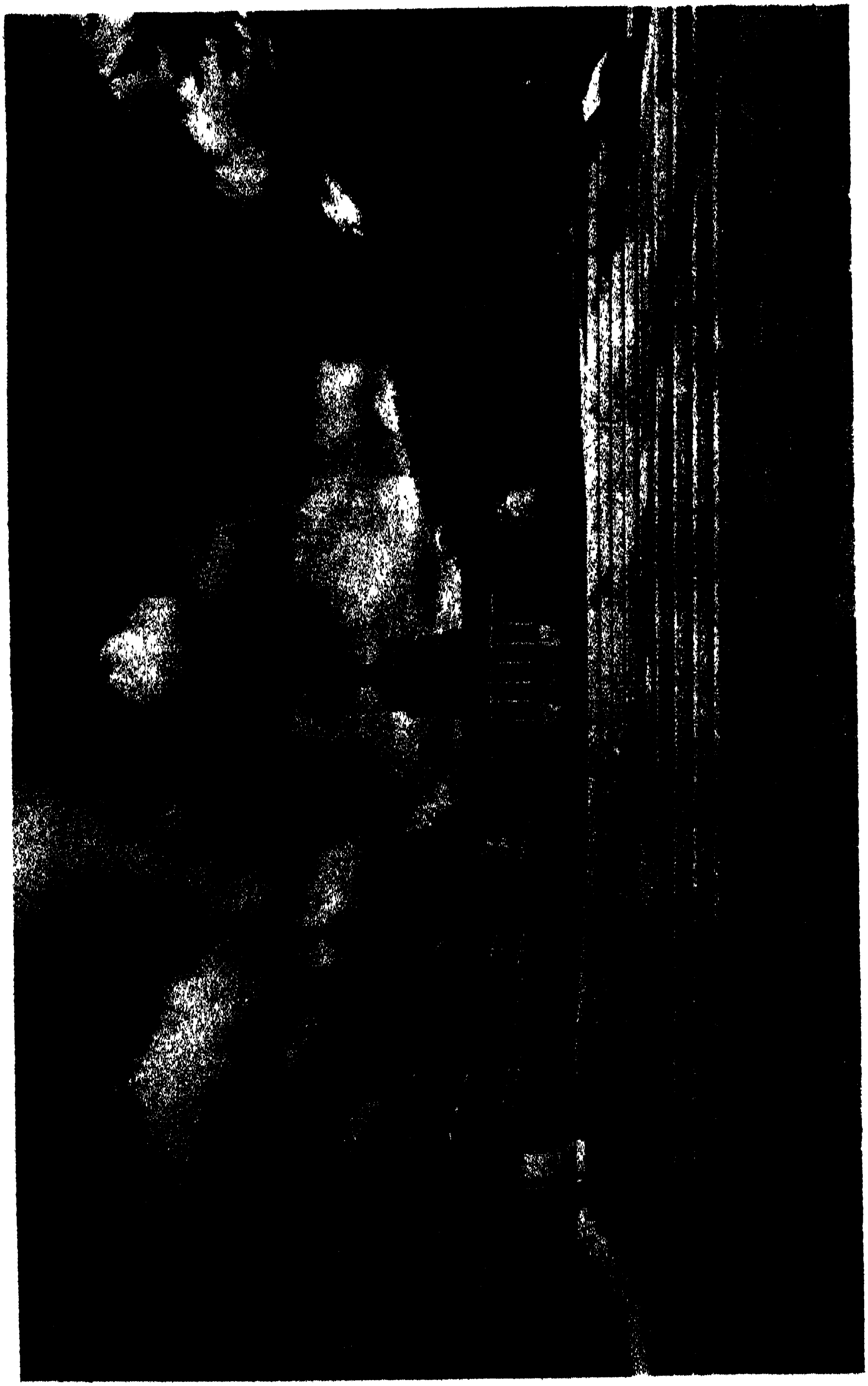
According to a recent British commentator, Rutherford "was by far the greatest living experimental scientist, and the greatest the world has seen since Faraday." This is a judgment that will be shared by most of those who know his work. In an age whose great achievement is its science, it would be fair to consider him as having been the world's first citizen.

ARTHUR H. COMPTON

THE ROCHESTER MEETING OF THE NATIONAL ACADEMY OF SCIENCES AND PRESENTATION OF THE COMSTOCK PRIZE TO PROFESSOR LAWRENCE

THE 1937 autumn meeting of the National Academy of Sciences was held at the University of Rochester, N. Y., on October 25, 26 and 27. The thirty-eight members of the academy who were present found themselves in a city of especial interest to men of science, by reason of its location in a region of great geological and historical importance, as well as its possession of remarkable technical industries and a rapidly developing university. The meeting was comfortably accommodated in the Strong Auditorium of the River Campus, beside the Genesee River, and surrounded by the new laboratories and classrooms of the College for Men.

The members were officially welcomed by President Valentine, to whom response was made by President Lillie of the academy. The scientific program, which occupied three mornings and one afternoon, comprised thirty-four papers. Of these only nine were presented by visiting members and guests, the rest coming from the various departments of the local university (with one from the Research Laboratories of the Eastman Kodak Company). The material presented was therefore predominantly biological, reflecting the activity of the young but important medical school and the recently reorganized biological department. Mathematics, physics, chemistry and geology were represented by ten contributions of which three came from the Institute of Optics of the uni-



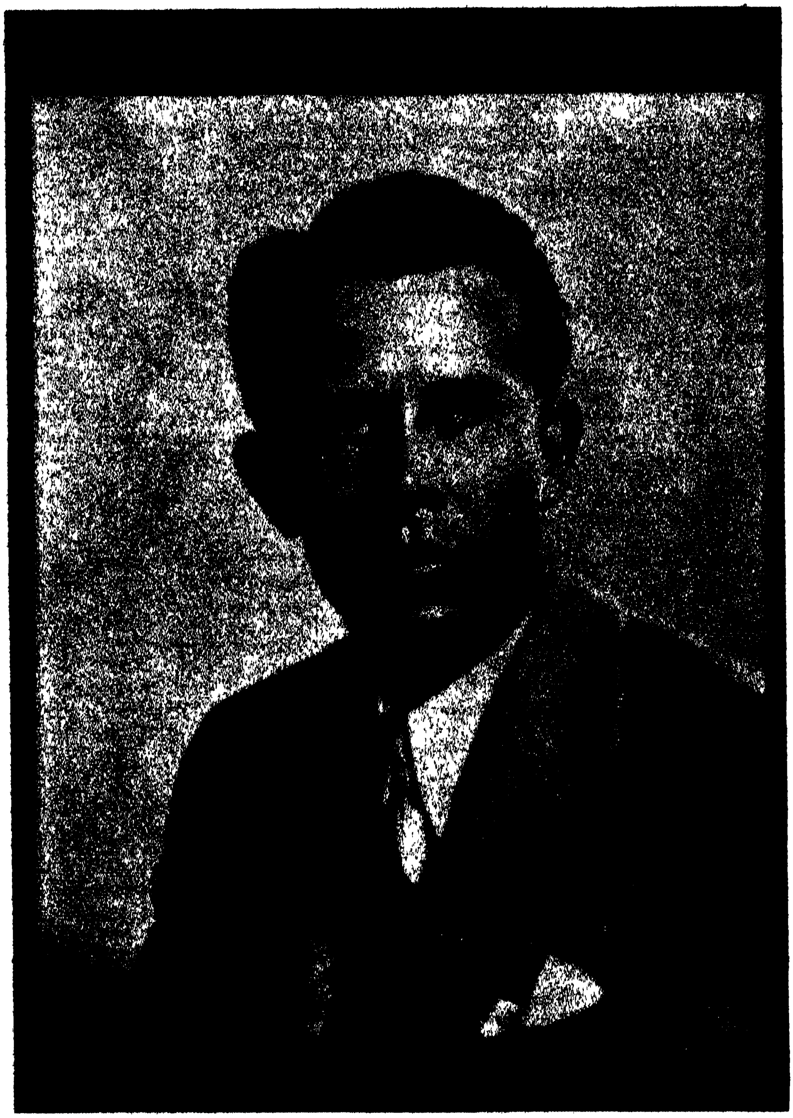
THE MAIN QUADRANGLE OF THE UNIVERSITY OF ROCHESTER versity and of the department of physics, also newly reorganized. The daily and weekly press took more than usual interest in the proceedings, sending a very competent corps of journalists, who reported many of the contributions at length.

On the afternoon of October 25 the members were received at tea by Dr. and Mrs. Valentine at Eastman House, the residence which the late George Eastman bequeathed to the university to be a home for its president. In the evening, in place of the usual lecture, the Symphony Orchestra of the Eastman School of Music gave a special concert in the great Eastman Theater, open to the public but held in honor of the members of the academy, for whom the mezzanine gallery was reserved. Before an audience of 1,400, the young musicians played with remarkable enthusiasm and technical skill under the leadership of Dr. Howard Hanson, director of the school, performing among other works Dr. Hanson's own "Romantic Symphony."

On the afternoon of October 26 there were inspection trips to two of the scientific industries upon which Rochester's fame is largely based, the Bausch and Lomb Optical Company and the Eastman Kodak Company. At their respective plants the visitors were divided into small groups and shown the work in progress in the research laboratories.

On the second evening of the session, October 26, a subscription dinner was held at the Genesee Valley Club. Arthur Parker, director of the Rochester Museum of Arts and Sciences, essayed as after-dinner speaker the difficult, even dangerous task of prophesying the future not only of the science of man but of man himself. The dinner was the occasion of the presentation of the Comstock Prize for achievement in the field of electricity to Dr. E. O. Lawrence, of the University of California. An address in explanation of the award was made by Dr. W. D. Coolidge, to which Dr. Lawrence responded in words of noteworthy dignity and charm. In the course of his remarks Dr. Coolidge said:

> Prior to 1919, we had no definite information concerning the interior of the nucleus of the atom. We knew that it had a positive charge equal to the sum of those of its extra-nuclear electrons. In addition to this, it was clear that the nuclei of the various chemical elements were all constructed from the same building blocks. But nothing was known about the nature of these blocks nor of the forces holding them together. The constitution of the nucleus was, then, one of the most fundamental problems that had ever presented itself to physical science.
>
> It was Lord Rutherford who opened the door to this rich storehouse of scientific knowledge By shooting alpha particles into nitrogen he was able to disintegrate the nitrogen nucleus with the formation of protons and an oxygen isotope. His classical experiment was followed by the bombardment of other elements with natural alpha particles and, in this way, the nuclei of nearly all the lighter elements up to calcium were transformed. With one exception, however, all attempts to transform the nuclei of the heavier elements had failed. Thus arose the urge to produce, artificially, particles having a higher energy content than those projected spontaneously from the radioactive elements. It was clear that, given sufficiently high voltages, such particles could be produced, provided suitable tubes could be developed to withstand these difficulties and seemingly serious limitations.
>
> Dr. Lawrence envisioned a radically different course—one which did not have those difficulties attendant upon the use of potential differences of millions of volts. At the start, however, it presented other difficulties and many uncertainties, and it is interesting to speculate on whether an older man, having had the same vision, would have ever attained its actual embodiment and successful conclusion. It called for boldness and faith and persistence to a degree rarely matched.
>
> In the magnetic resonance accelerator, or cyclotron, which Dr. Lawrence has created and developed, positively charged particles are accelerated so many times, as they circle about in a strong magnetic field, that they acquire energies of millions of electron volts, even though the actual accelerating potential difference is only a few tens of thousands. Not only this, but the limit to the particle energies which can be generated in this way is not yet in sight.
>
> Many serious difficulties have arisen and been successfully overcome. There has been, for example, the very vital problem of protecting human beings in the neighborhood from the extremely penetrating and dangerous radiations



DR. ERNEST O. LAWRENCE

PROFESSOR OF PHYSICS AND DIRECTOR OF THE RADIATION LABORATORY AT THE UNIVERSITY OF CALIFORNIA.

produced by the cyclotron discharge. Without much intelligent care many workers might well have been seriously injured. The value of the new tool is attested by its world-wide adoption and by the variety of scientific uses to which it is being put.

Dr. Lawrence has not only created and developed the cyclotron, but, in addition to this, he has been in the forefront of those actually using high energy particles in the assault on the nucleus. With high energy deuterons he has bombarded various elements, nearly all of which have been disintegrated by these particles, in most cases giving rise to new radioactive isotopes. These new artificial radioactive elements, which will soon be available in large quantities, can be used to investigate not only other nuclear phenomena, but also the mechanism of chemical and biological processes. They may also find important therapeutic uses.

THE INDIANAPOLIS MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

INDIANAPOLIS, INDIANA, is nearer the center of population of the United States than any other large city. It follows from the technical definition of "center of population" that there is no other city to which all the people in the country could go with so small a total of miles traveled. For this reason Indianapolis is an appropriate place for the annual meeting of the association, which will be held from December 27, 1937, to January 1, 1938.

There are, however, better reasons for holding the meeting of the association in Indianapolis. For example, it is one of the greatest railroad centers in the United States, having direct connections by through trains from the east and the west, from the north and the south. It is the capital of the State of Indiana, a fine city with a population of about 400,000. It is well supplied with modern hotels, it has a large number of places suitable for meetings near the center of the city, and it has excellent transportation. In these respects Indianapolis is exceptional, for its hotel, theater, banking and retail business district surrounds a circular plaza from the center of which rises an imposing soldier's and sailor's monument.

Since the American Association for the Advancement of Science through its fifteen sections and one hundred sixty-two affiliated societies covers practically all of pure and applied science, it appropriately gives a large amount of attention to the interrelations of the sciences and to the effects of science upon society and human beings as individuals. Several of the principal addresses are on such subjects.

"Science and Ethics" is the title of the retiring presidential address of Dr. Edwin G. Conklin of Princeton, which will be delivered on Monday evening, December 27. All who have been interested in the question whether science lays a new and better foundation for ethics will eagerly await Dr. Conklin's address. On Tuesday evening, December 28, Dr. Irving Langmuir, of Schenectady, New York, will deliver the annual Sigma Xi address, his subject being "The Physiological Significance of Moni-Molecular Films." In this address Dr. Langmuir will lead his audience out to the frontiers where science is discovering the nature of the physiological processes. Dr. George Lyman Kittredge, professor emeritus of Harvard University, will deliver the annual Phi Beta Kappa lecture on Wednesday evening, December 29. These Phi Beta Kappa addresses were inaugurated for the purpose of emphasizing the essential relationships that exist between science and general culture. Dr. Kittredge has chosen for his subject, "Shakespeare and the Critics." In addition to these addresses by distinguished scholars, there will probably be presented in excess of one thousand papers in the symposia and other sessions of the Indianapolis meeting. Only a few years ago not as many scientific papers were written in the United States in an entire year. Truly, the present rapid advance of science is one of the most remarkable phenomena in the whole history of the human race.

F. R. MOULTON

THE LAURA BRIDGMAN CENTENARY

DURING the autumn months of 1937 the Perkins Institution in Watertown, Mass., that venerable and honorable pioneer school for the blind, celebrated the centenary of the admission within its precincts of Laura Dewey Bridgman, the first blind deaf-mute to be taught the use of language.

When the first director of the institution, Dr. Samuel Gridley Howe, that doughty champion of human rights, heard of this triply handicapped child

SAMUEL G. HOWE, ABOUT 1859

of eight years, leading an isolated existence in her farmhouse home in Hanover, N. H., he determined to achieve what in similar instances learned physicists had declared to be impossible, by penetrating to her dormant mind.

LAURA BRIDGMAN

He easily persuaded her parents to entrust Laura to his care and set himself to the task of releasing her from the dark silence in which she was enshrouded. It was a trackless waste which confronted him, without guidance or precedent, and the path for the child's awakening, and for those coming after her, had to be hewn out by his own unaided efforts.

He has given a careful and authentic account of the long and tedious process by which, step by step, beginning with simple objects in daily use and the labels bearing their names in embossed type, he brought her to a realization of the connection of article and its name and, later, to the possibility of communication with those about her and, eventually, to full participation in normal life and activity around her, to appreciation of abstract truths and deep religious faith.

THE BRIDGMAN HOMESTEAD
ETNA, NEW HAMPSHIRE, WHERE A BRONZE TABLET IN MEMORY OF LAURA BRIDGMAN WAS UNVEILED ON OCTOBER 20, 1937.

Although there were many visits to her family in Hanover, Laura's life was centered in the institution which had opened its doors to her. There she found friendly companionship and a host of interests—reading, a voluminous correspondence, the making of exquisite articles of handwork, a share in plans for helping other handicapped children, even the teaching of newcomers to the

JAMES AND MARGARET ALLEN
DEAF-BLIND TWINS NOW AT THE PERKINS INSTITUTION FOR THE BLIND.

school—which kept her alert and happily occupied throughout her life, which came to a close in 1889, at the age of sixty years.

Her achievement was a veritable triumph for Dr. Howe. When, with Mrs. Howe, he traveled in Europe in 1843, he was everywhere acclaimed as Laura's deliverer, for the news of her awakening had been bruited abroad, especially through Dickens's fervid recital of the fact in his "American Notes," which led directly in after years to Helen Keller's emancipation. Dr. Howe was indeed Laura's deliverer and also a devoted foster-father, who cherished her as the child of his heart to the end of his life in 1876.

Many are the ways in which the memory of this first deaf-blind pupil is being kept alive, chief among them being a tablet, suitably inscribed and affixed to a boulder near her home in Hanover, and the assignment of her name in perpetual remembrance to one of the cottage dwellings of the institution which she had lovingly christened "Sunny Home."

The instruction of this shut-in being was important pioneer work, opening a new channel of human enterprise and endeavor. Its present-day methods, however, are no longer those of Dr. Howe, since his early experiments have been superseded in recent years by the more flexible and useful oral method, with articulation as the corner-stone. A well-planned and finely equipped department for the deaf-blind has been established at the institution, through specific, voluntary contributions, and no effort is spared to lead its pupils into the joy of life and thanksgiving which, with far less reason or opportunity, was Laura Bridgman's in full and satisfying measure.

LAURA BRIDGMAN
FIRST DEAF-BLIND PUPIL, TEACHING OLIVER CASWELL, ANOTHER DEAF-BLIND PUPIL AT THE PERKINS INSTITUTION FOR THE BLIND, ABOUT 1844.

A. G. F.

DEDICATION OF A MONUMENT TO PEARY AT HIS BIRTHPLACE

On the afternoon of October 15 a life-size bronze statue of Admiral Peary was unveiled at Cresson, Pa., close to the little house in which he was born on the sixth of May, 1856. The statue is the work of Joseph P. Pollia, and it shows

—*Photo by Johnstown Tribune*

MONUMENT TO PEARY

Peary in polar costume, with an Arctic dog running beside him. For the cost of the statue the children in the schools of Cresson and neighboring towns of Cambria County, Pa., contributed their pennies, and the grading and landscaping of the site, which is a dominating one in the fork of two great national highways, was done as a PWA project. At the back of the statue there is a stone hemicycle with benches for sitters, and a special parking place for cars has been prepared at the foot of the elevation.

Two thousand of the school children, led by their bands in uniform, marched in the procession which moved through the streets of the little town to the dedication ceremonies. Captain R. A. Bartlett, Peary's lieutenant, Matthew Henson, his Negro servant who stood with him at the Pole, and representatives of the Explorers Club, the National Geographic Society and the Geographical Society of Philadelphia were in attendance. The principal address was by Professor William H. Hobbs, of the University of Michigan, the biographer of Peary, and the statue was unveiled by Marie Peary Stafford and Peary Stafford, the daughter and the grandson of the great explorer

Addresses were made on behalf of the citizens of the town, county and state by Attorney P. J. Little, of Ebensburg, and Chief Justice John W. Kephart, of the Supreme Court of Pennsylvania. The ceremonies of dedication were under the auspices of the Rotary Club of Cresson.

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